Ph.D. Dissertation of Engineering

Data-driven Design Approaches for Vehicle Specification Changes

자동차 사양 변경을 실시간 반영하는 데이터 기반 디자인 접근 방법

AUGUST 2020

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Seoul National University
Department of Intelligence Convergence Systems

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지도교수 곽 노 준

이 논문을 공학박사 학위논문으로 제출함

2020년 8월

서울대학교 융합과학기술대학원

지능형융합시스템학과

이 민 구

이민구의 공학박사 학위 논문을 인준함

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Abstract

The automotive industry is entering a new phase in response to changes in the external environment through the expansion of eco-friendly electric/hydrogen vehicles and the simplification of modules during the manufacturing process. However, in the existing automotive industry, conflicts between structured production guidelines and various stake-holders, who are aligned with periodic production plans, can be problematic. For example, if there is a sudden need to change either production parts or situation-specific designs, it is often difficult for designers to reflect those requirements within the preexisting guidelines.

Automotive design includes comprehensive processes that represent the philosophy and ideology of a vehicle, and seeks to derive maximum value from the vehicle specifications. In this study, a system that displays information on parts/module components necessary for real-time design was proposed. Designers will be able to use this system in automotive design processes, based on data from various sources. By applying the system, three channels of information provision were established. These channels will aid in the replacement of specific component parts if an unexpected external problem occurs during the design process, and will help in understanding and using the components in advance.

The first approach is to visualize real-time data aggregation in automobile factories using Google Analytics, and to reflect these in "self-growing characters" to be provided to designers. Through this, it is possible to check production and quality status data in real time without the use of complicated labor resources such as command centers.

The second approach is to configure the data flow to be able to recognize and analyze the surrounding situation. This is done by applying the vehicle's camera to the CCTV in the inventory and distribution center, as well as the direction inside the vehicle. Therefore, it is possible to identify and record the parts' resources and real-time delivery status from the internal camera function without hesitation from existing stakeholders.

The final approach is to supply real-time databases of vehicle parts at the site of an accident for on-site repair, using a public API and sensor-based IoT. This allows the designer to obtain information on the behavior of parts to be replaced after accidents involving light contact, so that it can be reflected in the design of the vehicle. The advantage of using these three information channels is that designers can accurately understand and reflect the modules and components that are brought in during the automotive design process.

In order to easily compose the interface for the purpose of providing information, the information coming from the three channels is displayed in their respective, case-specific color in the CAD software that designers use in the automobile development process. Its eye tracking usability evaluation makes it easy for business designers to use as well. The improved evaluation process including usability test is also included in this study.

The impact of the research is both dashboard application and CAD system as well as data systems from case studies are currently reflected to the design ecosystem of the motors group.

keywords: data-driven, vehicle specification, context-aware, API, app, ioT

student number: 2010-31271

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Chapter 1

Introduction

Digital transformation rapidly changes society as well as industry. From new product development to product lifecycle management, data play a key role in business opportunity in various domains. In recent years, data science with respect to mobility has advanced with the development of the internet/intelligence of things.

1.1 Research Background

Vehicle design in the last decades were the innovative steps in the auto company. Designers could shape new lifestyle, shared platform, autonomous features within their perspective and suggest a lot of interfaces within their passion. However, several barriers like safety guideline, quality assurance, parts resourcing, and so on prevented new vehicle features from applying innovative design by the designers suggestion. Despite most of automakers have faced great renovation, the automotive domain has its rigid bureaucracy in traditional car manufacturing environment.

Parts procurement is especially a big problem. Less gain rates, high delivery charges, long production term periods are examples of problems. Even the vehicle designers suggest effective result in innovative design, the result sometimes can not be delivered to the place on demand.

Particularly, inventory storage, logistics and supply chain, are registered as ground due to the lack of reliability and the several stakeholders involved that commonly characterize the vehicle industry.

In the consumer side, an accident or a damaged section of a road that is temporarily unavailable for use (Chen et al., 2019) is one example where a detour will be required and users can be in critical situations as they commute to work (Redmond and Mokhtarian, 2001). In these cases, the driver as a consumer in car accident quickly requires repair of the car in accident to continue one's commute while the driver in the other vehicle must know the adequate detour route. Not all repair parts are prepared nearby and the car in the accident might be towed to repair for long distance. Car designers can't expect it yet.

1.2 Objective and Scope

In the production and manufacturing industry, it is the role of designers to create value systems and make efficient use of available resources. This indicates the designers' need to develop creative methods of generating a virtuous cycle in the product-environment system. Due to the growth in un-tact business since the COVID 19 pandemic, the importance of communication is ever increasing in design tasks in remote environments.

Aims of the study is to provide differentiated approaches for automotive designer as the industry stakeholders (users, investors, traffic authorities, vendors, third parties, and so on) can get to represent designer's needs as well as their perspectives. In this viewpoint, the chapters included in this dissertation discuss the aim and current state of the art to build consensus of originated challenges in the ”data system for automotive designer” framework and the method the related user experience research and design would accommodate the related pedagogical principles. It includes not only application areas and software tools, but also guidelines and infrastructures from the employee-centered point as well as user-centered point.

1.3 Environmental Changes

As an alternative to gasoline and diesel cars that consume fossil fuels, eco-friendly vehicles, such as electric and hydrogen cars, will occupy a higher percentage in the future production of automobiles. Moreover, the automation of vehicles since the 2000s is another significant change in the automobile industry. The integration of automotive semiconductor and addition of new features emerge alternatingly, and as a result of such a pattern, the number of automotive parts rises up to a certain point and falls. On a long-term perspective, the number ultimately decreases as the gadgets can be assembled and replaced by modules. This modularisation is reinforced by the increased production of eco-friendly cars and automation of vehicles. Therefore, it is the responsibility of automotive designers to conceive of various ways in which easily-replaceable designs — due to legal, environmental and practical issues — can be appropriately used or prepared upon.

1.4 Research Method

This section illustrates which method is applied to solve the problem in each chapter. The order of method is according to the stream of the research. Basically, I researched the in-house mobility industry project in the motors company group to take part in the inclusive design inside the automotive field in its embedded environment. Through design studies, qualitative processes such as customer experience audit, eye tracking, mental model diagrams, semantic differences have been executed for the results. The participatory behavior research approach through user travel is mapped from the user's lead to the evidence-based design. I summarized qualitative component analysis with graphical model to figure out the cause and effect with diagrammatic description in Chapter 5 to 6.

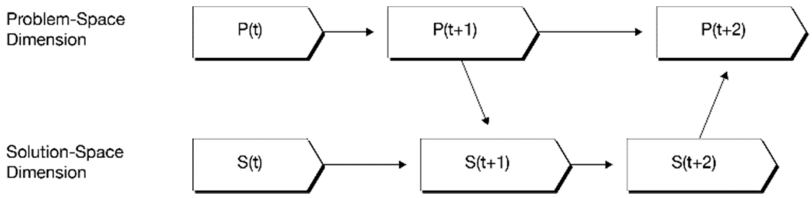


Figure 1.1: Process of co-evolution of problem-solution. P(t) and S(t) are interactive

1.4.1 Design Thinking Methodology with Co-Evolution

Design thinking is a sequential qualitative research method to reflect the needs of users [24]. Design thinking commonly starts with understanding and consists of four stages like discover - define - develop - deliver. For problem solving in qualitative approach without defined problems, I started discovering components to assimilate insights and check findings. Accordingly, needs were extracted from user facts to define real world problems. After defining the problems, developing for the design implementation is shared for both hardware (product) and software (web/app/legacy) design. Delivery is the last stage to shape the result of design thinking.

According to the Dorst and Cross (2001), co-evolution is one approach to construct a series of system including problem and solution space. It starts with first design concept with original problem defined, and find alternative solution which includes next problem newly appeared.

Dorst and Cross (Ibid., 2001) developed the design thinking and its model to "Co-evolution of problem-solution" dealing with the problem-space dimension [25], as shown in Figure 4. The dimension of problem-space and solution-space evolve and develop cooperatively with each other. I considered a lot of variables that occur on the road and set up a system that manages data in an integrated way in the co-evolved design process. It represents the phase of solutions with problems.

The initial problem and solution spaces, respectively; P(t+1) and S(t+1) are the partial structuring of problem and solution spaces, respectively; P(t+2) and S(t+2) are the developed structuring of problem and solution spaces, respectively. Design thinking follows the 4D process of ‘Discover’, ‘Define’, ‘Develop’, and ‘Deliver’. The four processes are discussed as below.

1.4.2 Required Resources

Though the size of project or problem is too huge to deal with, one approach is to divide it to several parts, to reduce complexity from the size. On the opposite side of the network effect, parts of project/problem spilt over from the whole body has smaller complexity.

1.5 Research Flow

Environmental changes innovates the society very quickly. Automotive field will also meet the disruptive movements from the digital transformation. Important thing is how to illustrate how to deal with specification related information for supporting designer as a system in the automotive industry. The system advises automotive designers in real-time approach to avoid risks from the external changes around the auto market. This study executes implementation on real-time information support system for designer, within flow of the research below:

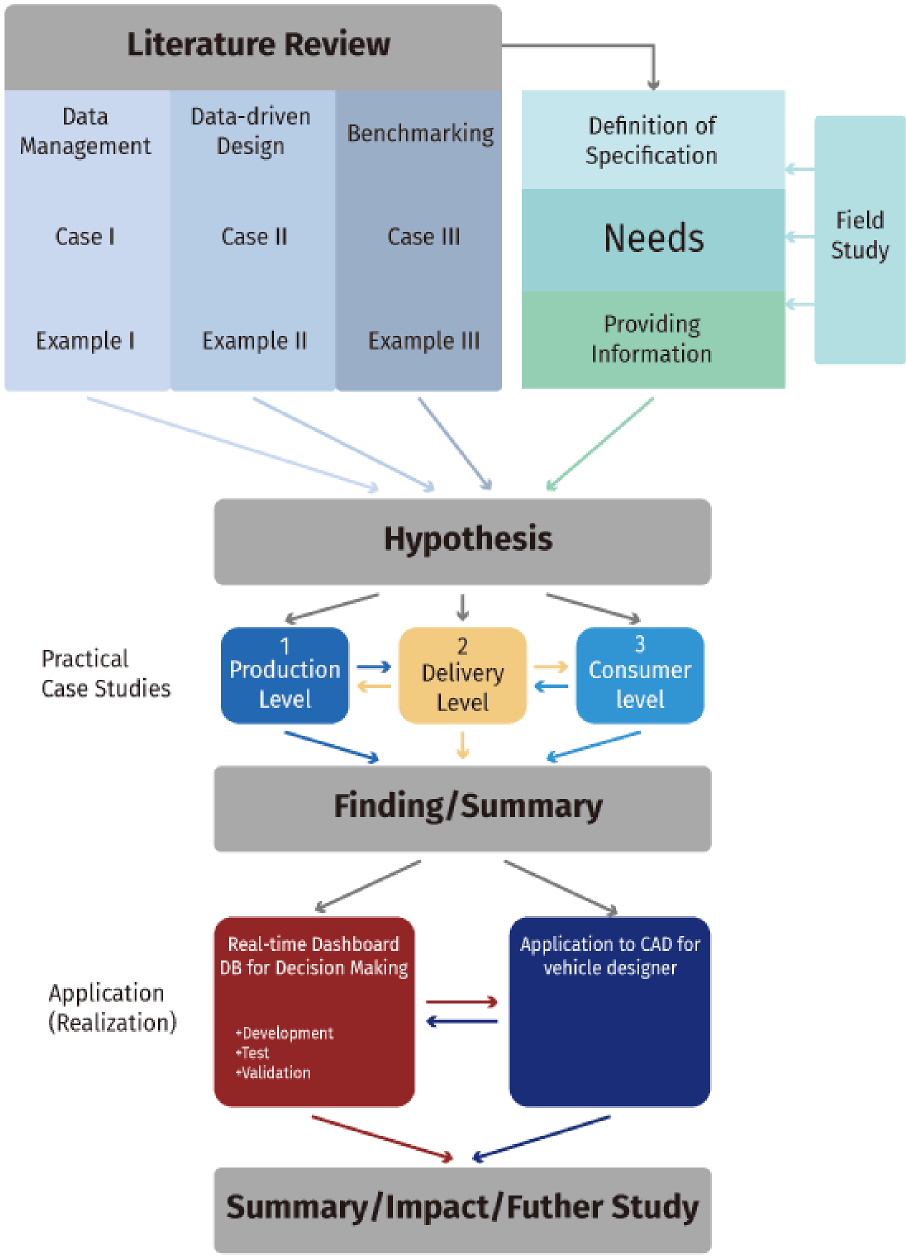


Figure 1.2: Flow of the research.

Chapter 2

Data-driven Design

2.1 Big Data and Data Management

2.1.1 Artificial Intelligence and Data Economy

Automotive market is facing a new era to innovate itself. Based on the data from the website Statista.com, worldwide vehicle sales reached a record 91.3 million vehicles in 2019, down 4 to 5% from 2018. Though the market size is enlarging in steady state, global automotive industry is facing the disruptive challenge from autonomous, electric and sharing.

In the process of new product development, it is necessary to understand elements and attributes of the system. Especially for effective product specification management[3], engineering properties as well as design properties are emphasized according to the signals from external environments. The research purpose of this chapter is to understand and analyze the structures used in the development of specifications for the automotive industry.

For several reasons, the automotive field stakeholders have not reached the ”grace of the technologies” yet, and the most researches in the automotive fields are related to the information security and assurance.

2.1.2 API (Application Programming Interface)

Application programming interface (API) is a kind of computing interface which defines interactions between multiple software intermediaries. (Sharon, 1989) API provides extension mechanisms to extend existing functionality for users in various ways with varying degrees. Several requests or calls can be made to the data formats that could be used in the system. For example, density of dust can be provided by ”Air Korea” APIs system operated both by Korea environment corporation and Korea meteorological administration. (https://www.airkorea.or.kr/eng)

2.1.3 AI driven Data Management for Designer

Product and manufacturing information (PMI) is used in 3D CAD and collaborative product development systems to convey human-readable information about the design of a product’s components for manufacturing. (NIST, 2018 at go.usa.gov/mGVm) In more specific point, PMI conveys information such as geometric dimensioning and tolerancing, 3D annotation (text), surface finish and material specifications and other additional information. (Siemens, 2011, NIST, 2018)

As JSON is also human-readable, both PMI and JSON can be converted to xml, an input-output AI system assembled with 3D CAD is available interface to be implemented. PMI itself is able to be created by context-aware environment by generative Artificial Intelligence.

A more comprehensive set of PMI is required by designers, as it does not only contain essential information for manufacture-based designs, but also offers field knowledge and insights into the problems related to the ecosystem of automotive parts. Designers have found it challenging to receive such information in the previous design processes, and hence, it is the aim of the proposed application to help transfer PMI in a machine-deliverable method in artificial intelligence environment.

2.2 Datatype from Automotive Industry

2.2.1 Data-driven Management in Automotive Industry

When a vehicle designer can anticipate the problem of the component ahead of time, the motor company can discuss the use of alternative parts in the early stage of design in its process. If the designer already understood the causal inference of the part and design concept aforetime, designer's choice of the component might be different, away from risks. But no angel whispers vehicle designer the information of the future.

2.2.2 Automotive Parts Case Studies

There are several thousands of parts are assembled in the vehicle. Bill of material (BOM) represents hierarchy of parts assembly structure in order to execute the function. I took part in the automotive parts case studies from human-machine interface (HMI), semiconductors to RADAR and sensor packages as a in-house researcher in the motors group.

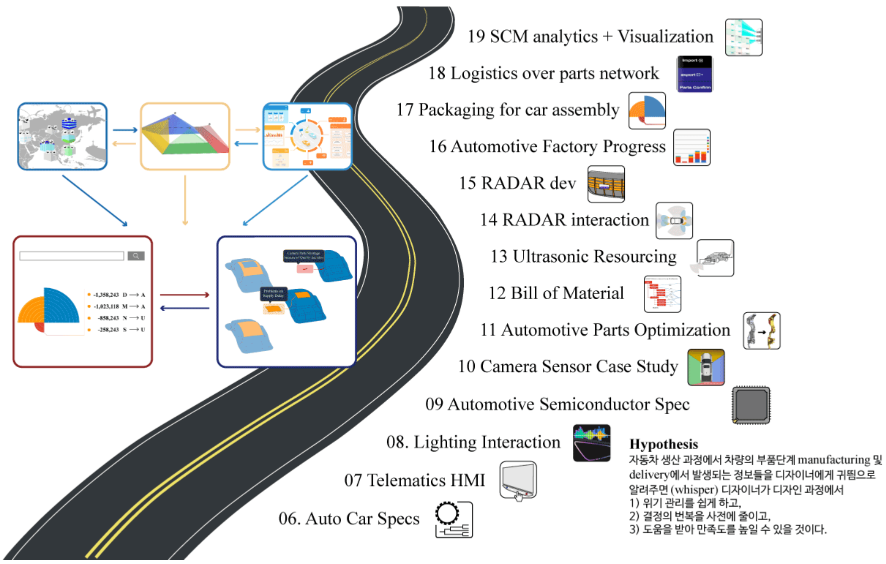


Figure 2.1: Participation on automotive parts case studies from YR 2006 to 2019.

2.2.3 Parameter for Generative Design

Numeric parameters permitted in the specification of the parts will divide the parts with two, available and unavailable ones. To support designers by providing helpful information which to avoid risks, I wanted to introduce intellectual technologies to inform it. For example, a digitally provided item of an alternative parts in a CAD display will allow great chance to reshape the product at once in its user interface for automotive designer.

2.3 Examples of Data-driven Design

2.3.1 Responsive-reactive

To display contents in the information device, the size of the display width and height depends on the layout design of the contents. Responsive design adjusts to ”the screen size and orientation of a connected device” with issues on ”squished graphs and resized legends” in its infographic (Elliot et al., 2019). Reactive design focuses on ”how a website responds to users’ interactions”, in particular, ”the speed and sensibility of response to human input” (ibid., 2019). In mobile design projects, ”data-driven models help mobile app designers understand best practices and trends” (Deka et al., 2017). Data-driven can be used ”to make predictions about design performance and support the creation of adaptive user interfaces” (ibid., 2017).

2.3.2 Dynamic Document Design

Business Intelligence

”Business intelligence (BI) is a technology-driven process for analyzing data and presenting actionable information which helps executives, managers and other corporate end users make informed business decisions. BI encompasses a wide variety of tools, applications and methodologies that enable organizations to collect data from internal systems and external sources, prepare it for analysis, develop and run queries against that data and create reports, dashboards and data visualizations to make the analytical results available to corporate decision-makers, as well as operational workers" (Rouse, 2019).

Kiosk

Kiosks are "computer-based information and transaction systems offering access to information and/or transactions for varying groups of users with typically short dialogue times and a simple user interface in publicly accessible places". (Mahmut, 2016) Kiosk is one common example that shows dynamic documentation in locally installed housing computers.

Integrated Dashboard

Visualization of information is able to be defined as "the use of interactive visual representations of abstract data to amplify cognition" (Ware, 2012). By a lot of researches, the importance of "integrating graphical representations of diverse performance analysis in a single dashboard" was emphasized. That means, multiple information sources might be gathered and displayed simultaneously in one dashboard.

2.3.3 Insignts from Data-driven Design

Design process is not one direction, but interactive way to reflect the generated data in the process. It is recursive way that continuously response to the demand from whole ecosystem. Key approach is how frequently react to the real-time information rush.

To apply real-time information, it requires semi-automatic reflection of the data to the design components or supplementary materials during the design process.

Chapter 3

Benchmark of Data-driven Automotive Design

3.1 Approach of Global Benchmarking

Benchmarking is the comparative practice of comparing operation processes or performance metrics to industry bests and best practices from other examples. The in-vehicle benchmarking process is for which standalone component test data was available. The benchmarking process in which various additional sensors were installed to cross-check operational parameters. The intent of this investigation was planned to create a robust evaluation process that would not be followed with ”a prior knowledge of component performance”, either ”additional instrumentation installed in the vehicle”[9].

In this study, I utilized benchmarking process to compare and figure out the specification with the opinion of alternative parts to meet the function and to avoid the risk from newly provided information from the field. For example, Tesla motors in year 2020 provide three specification data - 1) range, 2) cargo space, 3) duration from 0-60 mph - in the front page of their model website[18] to reveal their performance. Picking exampled three specification items applied to comparison with the other carmakers' design point.

3.2 Automotive Design

3.2.1 HMI Design and UI/UX

Multimedia front panel is the face of centerfacia. It is called not only as the face of the cockpit, but as the face of the car. The design of the display in an identical model is subject to changes depending on the duration of distribution and country of sale. For example, when using an organic liquid-crystal display, there is a specific range of temperature, at which the carbon compounds of the display can remain stable. Given that the display can withstand temperature from -45 degrees Celsius to +125 degrees Celsius, a different part would be required for extreme climates, such as in the Northern Europe or regions near the Equator. In this study, I have one example of Front panel part which is conceptually proposed within industrial technology of the point.

Front panel parts in the centerfacia with organic electroluminescence (OLED) capacitive-sensing touchable input interface in one vehicle model initially includes 35% of defeats in its production. Because production technology can't meet the gain rate yet to mass-produce the panel in year 2009. It took nearly ten more years to make profit with the OLED touchable parts production in the display vendor. The innovative design of the panel couldn't make market value for long.

Figure 3.1: Front panel - touchable OLED.

3.2.2 Hardware Design

Vehicle Package Design

Mechanical Design

3.2.3 Software Design

According to the AUTOSAR standard, vehicle software design is depend on the safety requirement. Autonomous or automated driving stages are reflected in the SW.

3.2.4 Convergence Design Process Model

The convergence design process comprises of two sub processes; the hardware design process and the software and UI/UX development process, which have a sequential order according to the task and guide. The order of processes is (1) product design steps from planning to implementation, and (2) application software design steps from IA to release version. The process of convergence design is shown in Figure 3.2. Both design processes Ire conducted in the following stages: planning research, development, and productization. Each design process contains three stages: user research, design enhancement, and productization and interactively modeled with co-evolution of problem-solution mentioned in Figure 3.2.

3.3 Component Design Management

Change of vehicle components has merit to upgrade its components and renew the vehicle itself to meet the customer requirement. From smaller to bigger changes, there are separated levels of variation including engineering order (EO), material modification (4M/6M), improvement of product (IMP), model year design change (MY), face lift design (F/L), minor/major change, full model change and new product design. Those changes are called as specification change in the perspective of design.

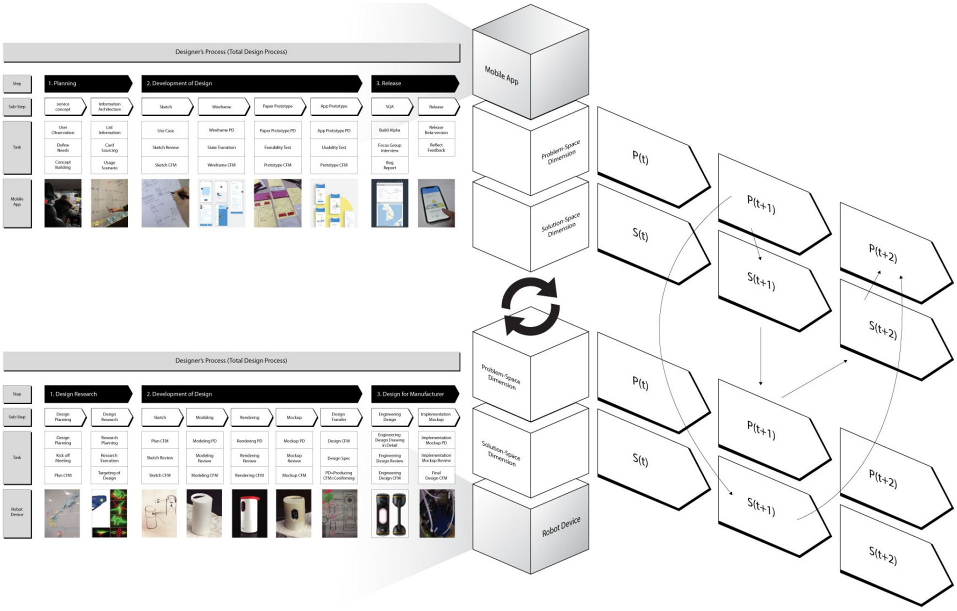


Figure 3.2: The total design process and thumbnails of sensor robot applied in the highways/roads with the converged mobile app.

Table 3.1: Levels of variation according to the change of vehicle component

#type of change	structural change	spec range	effect	period
Engineering order	target function	target parts	much	frequently
Material modification	material	target module	much	frequently
Improvement of prod*	new technology	electronics	much	6 months
Model year change	interior/exterior	F/R grill	much	1 yr
Face lift	interior/exterior	F/R lamp	much	1.5-2 yr
Minor change	interior/exterior	body/seat	much	1.5-2 yr
Major change	interior/exterior	body/seat	much	1.5-2 yr
Full model change	fully except for chassis	engine/susp*	less	4-5 yr
New product design	whole structure	W-D-H	none	scheduled

Chapter 4

Vehicle Specification Design in Mobility Industry

Government-certified Standard Fuel Efficiency and Class		
Trim A	Gasoline 2.0(16 inch)	Government-Declared Fuel Efficiency - Combined 13.1km/ℓ(City : 11.7km/ℓ, Highway : 15.1km/ℓ) CO2 Emissions : 128g/km | Displacement : 1,999cc | Empty Vehicle Weight : 1,405kg | Automatic 6-gear (class 3)
	Gasoline 2.0(17 inch)	Government-Declared Fuel Efficiency - Combined 13.3km/ℓ(City : 11.9km/ℓ, Highway : 15.5km/ℓ) CO2 Emissions : 126g/km | Displacement : 1,999cc | Empty Vehicle Weight : 1,415kg | Automatic 6-gear (class 3)
	Gasoline 2.0(18 inch)	Government-Declared Fuel Efficiency - Combined 13.0km/ℓ(City : 11.6km/ℓ, Highway : 15.0km/ℓ) CO2 Emissions : 129g/km | Displacement : 1,999cc | Empty Vehicle Weight : 1,470kg | Automatic 6-gear (class 3)
	LPi 2.0(16/17 inch)	Government-Declared Fuel Efficiency - Combined 10.3km/ℓ(City : 9.1km/ℓ, Highway : 12.1km/ℓ) CO2 Emissions : 126g/km | Displacement : 1,999cc | Empty Vehicle Weight : 1,410kg | Automatic 6-gear (class 4)
	LPi 2.0(18 inch)	Government-Declared Fuel Efficiency - Combined 9.8km/ℓ(City : 8.7km/ℓ, Highway : 11.5km/ℓ) CO2 Emissions : 133g/km | Displacement : 1,999cc | Empty Vehicle Weight : 1,475kg | Automatic 6-gear (class 4)
Trim B	Gasoline 1.6 Turbo(17 inch)	Government-Declared Fuel Efficiency - Combined 13.7km/ℓ(City : 12.3km/ℓ, Highway : 15.9km/ℓ) CO2 Emissions : 122g/km | Displacement : 1,598cc | Empty Vehicle Weight : 1,420kg | Automatic 8-gear (class 3)
	Gasoline 1.6 Turbo(18 inch)	Government-Declared Fuel Efficiency - Combined 13.2km/ℓ(City : 11.8km/ℓ, Highway : 15.2km/ℓ) CO2 Emissions : 127g/km | Displacement : 1,598cc | Empty Vehicle Weight : 1,460kg | Automatic 8-gear (class 3)
	Gasoline 1.6 Turbo(19 inch)	Government-Declared Fuel Efficiency - Combined 12.8km/ℓ(City : 11.3km/ℓ, Highway : 15.1km/ℓ) CO2 Emissions : 131g/km | Displacement : 1,598cc | Empty Vehicle Weight : 1,490kg | Automatic 8-gear (class 3)
	Gasoline 1.6 Turbo(19 inch) + Built-in cam	Government-Declared Fuel Efficiency - Combined 12.6km/ℓ(City : 11.3km/ℓ, Highway : 14.6km/ℓ) CO2 Emissions : 134g/km | Displacement : 1,598cc | Empty Vehicle Weight : 1,490kg | Automatic 8-gear (class 3)

Figure 4.1: Vehicle specification example - engine platform leveraging for consumer's side.

Category	Trim A Smartstream G2.0	Trim B Smartstream G1.6T	Trim A' Smartstream L2.0
Overall Length (mm)	4,900	4,900	4,900
Overall Width (mm)	1,860	1,860	1,860
Overall Height (mm)	1,445	1,445	1,445
Wheel Base (mm)	2,840	2,840	2,840
Wheel Tread, Front (mm))	1,633(16") / 1,623(17") / 1,618(18")	1,623(17") / 1,618(18") / 1,610(19")	1,633(16") / 1,623(17") / 1,618(18")
Wheel Tread, Rear (mm)	1,640(16") / 1,630(17") / 1,625(18")	1,630(17") / 1,625(18") / 1,617(19")	1,640(16") / 1,630(17") / 1,625(18")
Engine type	Smartstream G2.0	Smartstream G1.6T	Smartstream L2.0
Displacement (cc)	1,999	1,598	1,999
Max. Power (PS/rpm)	160 / 6,500	180 / 5,500	146 / 6,000
Max. Torque (kg.m/rpm)	20.0 / 4,800	27.0 / 1,500~4,500	19.5 / 4,200
Fuel Tank (ℓ)	60	60	64

Figure 4.2: Vehicle specification example - overall body information for consumer's side.

4.1 Definition of Vehicle Specification

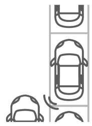
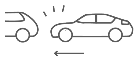
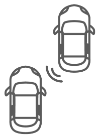
When a vehicle is developed for market, the needs of consumers/customers are certainly taken into consideration. A "vehicle specification" is designed to meet the needs of customers[19]. Hardware parts assembly decides the trim of the vehicle.

The example of vehicle specification management today is depend much on both product value and risk management.

In order to diversify products, product specification management is the most important. Product specifications refer to the performance and system characteristics that the product must exhibit in order to satisfy the consumer. In the paradigm of multivariate variable order production, product specification management to make various types of products in a variety of ways is being actively researched.

Designers also actively participate in the management of product specifications during product development. The automotive industry requires designer plays a liaison role in product specification management, from the initial product planning process to

Table 4.1: Trim comparison example according to the vehicle specification

#items				
#parts	MFR Full LED	Smart PAS	Smart CC	BS Detection
Trim A	V	V		
Trim B		V	V	
Trim C		V		V
Trim D			V	V

product design, mechanical design, and mass production design. In the auto industry with high added value, the demand for design review and enhancement of emotional quality is reflected to improve product diversity.

Design review deals with those kind of directions in one table. Endless discussion to represent the specification is diversified but not converged with various majorities. Marketing, sales, manufacturing, procurement, quality, and employee safety departments are appealing against design result while their index objective seems to be on the higher priority.

The issues of automotive specification management is existence of guideline like quality evaluation table and parts procurement, and so on. It's a problem of aspirin vs. vitamin.

4.2 Field Study

In automotive industry, knowledge is too domain-specific to be delivered by education. It is only stacked from the work experience (mostly from the failure) of case studies. Workers in automotive industry are not willing to innovate the work procedure, by themselves as well as by other researchers. They tend to succeed strictly. Only by formal succession/accession is the route knowledge is delivered.

As for the limited communication channel, vehicle specification information is manually transferred to others with example cases arranged by part numbers. From the factory for manufacturing, through the logistics center for delivery, and to the repair shop for consumer, automotive industry is gathering specification information and its experience distinguished by vehicle parts.

For example, the assembly-line worker manufactures cockpit area of the vehicle model II. The line worker has to connect rear media connector to the head unit, but can misunderstand the specification and result in connecting ODD connector instead. Color coding is not enough for novice assembler. Mechanic assembly parts requires distinguished connector figures over two different connectors on rear media and ODD to avoid mismatch. But the connector figure is standardized in its specification by ISO guideline. How can designer redesign the both side of the connector assembly? Temporary solution of distinguishing was to identify with additional cap which was covered to the ODD connector.

For another example, supply chain management including inventory and logistics are thought of as original circumstances due to the several vendors involved. While there is a lack of trust in parts resourcing, the designer's results typically symbolize inconsistencies in the manufacturing industry without flaws. Providing an information data-oriented service to manage the expendable automotive parts is prepared through this research.

4.3 Hypothesis

It is hypothesised that if the designer is informed of the stages in the automotive parts manufacture and delivery, they will be able to 1) perform risk management more easily, 2) prevent the revoking of any decisions beforehand, 3) increase flexibility in the their design process. I extracted three research questions like:

- What is the product specifications risk when it is determined and changed in the product lifecycle management of automobiles? - And how can designer overcome the risk?

- How the vehicle designer affected and which roles designers do against the vehicle's product specification change? - And what makes it easier?
- How the data-driven system is able to respond flexibly to product specification changes to support the designer's role? - And which interface is required?

Distribution of the vehicle parts is a kind of journey. The automotive parts is manufactured in the factory and delivered through logistics center and sales representative (agency) and provided to consumer in the sales shop or repair shop. I will describe the information sharing with three stages like production level, delivery level and consumer level in the chapter 5

Chapter 5

Three Preliminary Practical Case Studies for Vehicle Specification to Data-driven

This chapter is written based on published articles below:

- Lee, M.; Kim, J.; Jeong, H.; Pham, A.; Lee, C.; Lee, P.; Soe, T.; Kim, S.-W.; Eune, J. Communication with Self-Growing Character to Develop Physically Growing Robot Toy Agent. Appl. Sci. 2020, 10, 923.

- Lee, M.; Park, J. Solving Kinematics Simulation on the Structure of Camera-based Automotive Environmental Parking Monitoring Systems. Proceedings of KSAE 2011 Autumn Conference, 2011, 1299-1313.

- Lee, M.; Won, J.; Kim, J.; Jeon, H.; Hong, I.; Jung, E.; Jin, T.; Jeong, S.; Ga, S.-H.; Kim, C.-J.; Eune, J. Safety Lighting Sensor Robots Communicate in the Middle of the Highway/Roads. Appl. Sci. 2020, 10, 2353.

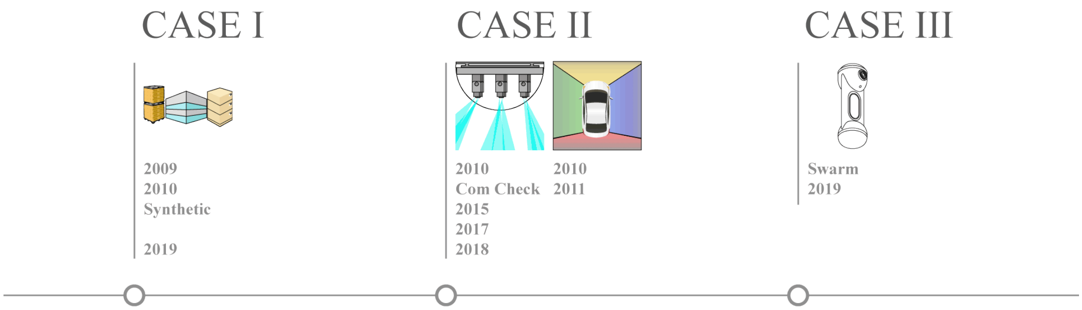


Figure 5.1: Three Preliminary Practical Case Studies - Mobility Industry Projects

5.1 Production Level

PMI is firstly available in the production level from the factory of manufacturing business. It represents micro perspective view for individual automotive parts. On the macro eyesight, manufacturing factory itself is concerning many of parts in simultaneous cycle time. Automotive parts manufacturing lines are resistant and evolve as they face crises such as shortages and strikes as if they were living creatures.

5.1.1 Background and Input

The production manager of the automotive industry has less time to decide with the information separately gathered from various channel. That factory manager can interact with other people's emotional expressions through a robot. Step by step, the robot character will grow as the guideline grows. The goal of the trial is applying robot design platform to vehicle modules.

As an independent synthetic character, the robot was recognized by user which had the designed function. Robots for training may require more experimentation. In recent twenty years, tremendous amount of robot research has been devoted to the replacement work by the robot. On the other hand, few researches have shown the simulation of communication between human and robots. Especially for example, children under age 10 are more likely to involve in the interaction with robots because they perceive robots more in friendly and positive way. Besides, robot design based on user research of assistance and collaboration robots have become an important research issue over various industries.

The mission of previous conceptual research in motivating targeted user in learning with synthetic character by means of information provider. I managed a design process of a teaching assistant robot interaction system that can optimize empathy by using techniques in previous researches. Embedded tech specification within an acceptable artificial neural network to perform a teaching assistant rule can induce users' learning motivation and reduce novelty effect. Based on the following example of robot "Buddy"(Lee et al., 2017), the research on the character of the growing robot character and the empathetic interaction is used to verify that the robot character can be used as a means of empathy communicator that can serve as a teaching assistant role as well as guide visualization role.

This research considers an example of how the synthetic characteristics can be applied to the quantitative growth of factory manufacturing lines through the product design process. With the development of character for factory and warehouse, two variations on the character were made to achieve recognizable growth. (1) A one-dimensional height scaling with legs and (2) various facial expression for status signal including the distance change between two eyes.

5.1.2 Data Process from Inventory to Designer

Past approaches on manufacturing information service have shown human-made data resourcing to reveal the current status of manufacturing operation from all manufacturers spread over.

I proposed an information gathering system for designer to support data-driven design. To meet the vehicle specification changes originated from the customers' needs, demand response channel might be connected and linked to the factory manufacturing system of automakers and parts makers.

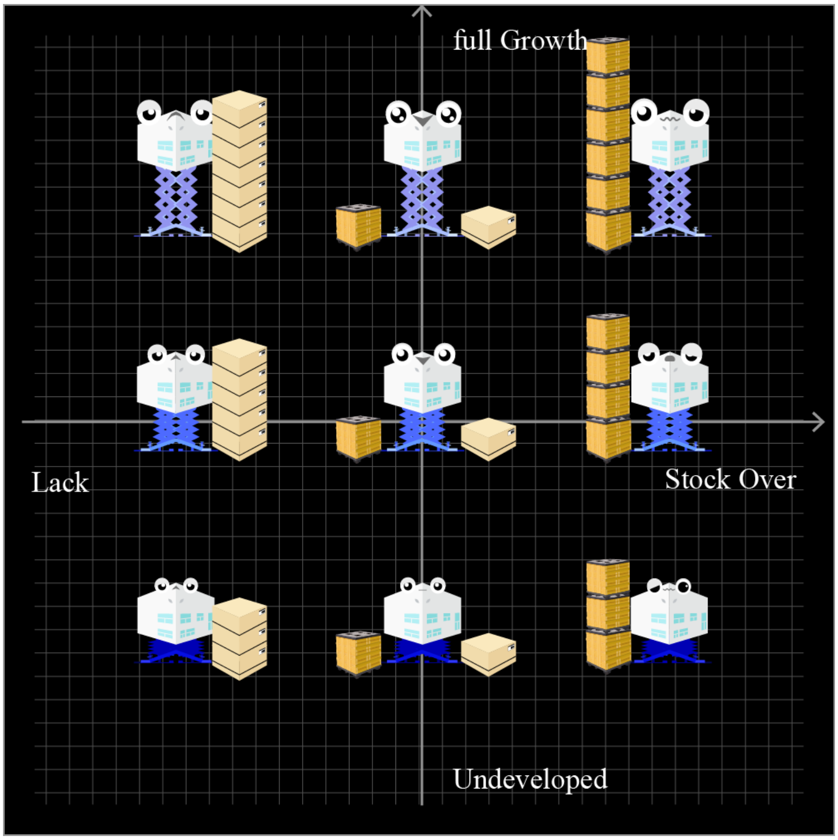


Figure 5.2: Factory status information displayed on synthetic warehouse character.

Applying synthetic character design insights to build platform for visualizing vehicle factory modules is the intended goal of this research. As shown in Figure 5.2, two axes are introduced for the categorizing vehicle factories: inventory in x axis and operation in y axis.

The left side of the character shows how many inbound materials factory contains, and the right side shows the outbound which is the result of manufacturing to be delivered. The Figure 5.3 shows the application how to design figures to represent the status of vehicle manufacturing - factories and inventories worldwide.

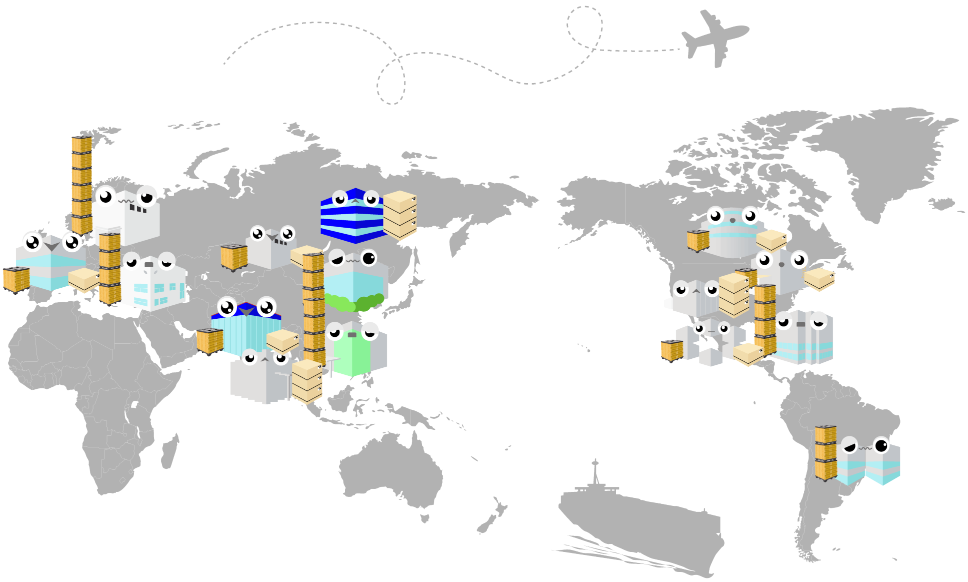


Figure 5.3: Factory-warehouse characters to display worldwide inbound/outbound stat.

5.1.3 Output to Designer

While designing the trim according to the vehicle specification, designer can check the productivity of the designated parts and get real-time resourcing information of the automotive parts or vehicle function module. The next thing is delivery of that parts.

5.2 CASE I: Surrounded View Monitoring for Feedback Ecosystem

5.3 Case Study Background

Personal mobility concept has wide-spread all over the world. As for last mile mobility units, personal mobility is shaping the way billions of people live. Moreover, it is deeply influencing the ecosystems where vehicles were manufactured in the factory and developed from the design house. This section is based upon the research article "Solving Kinematics Simulation on the Structure of Camera-based Automotive Environmental Parking Monitoring Systems (Lee and Park, 2011)".

Surrounded view Monitor is the system for helping driver find exact position while parking the car, reflecting visual aspects from four-outside cameras around the vehicle. Front and rear, left and right, there are two couples of distinguished cameras settled in order to reveal the obstacles outside the vehicle. The object appeared around the vehicle is captured artificially as if I look around the vehicle in the view above it, like in the sky, in real-time. Problem occurred on the angle of camera on the present monitoring system, which is determined and distinguished according to length and width of each vehicle model.

Several vernacular approaches for deciding angles of monitoring camera were in common. Because of physical volume of each vehicle, four-point camera setting was customized only for the only model of the vehicle. Instead, a size-oriented approach for automatic deciding angles of camera is presented in this paper. This approach calls for the determination of available angle configurations and calibrations, which is based on the link and joint coordinate systems and robot arm mechanism. These adjustments are presented in two accurate mathematical ways to permit the production of mounting construction indicators and their relative motion equations.

The construction indicators, (representing adaptive lengths and angles of settlement links) are configured by factory setup for the purpose of jointing four cameras for monitoring This paper describes on the calculation of a simplified three-dimensional mathematical model of vehicle camera attachments for the purpose of developing real-time parking guide system, and applying the parking environment to several different characteristics of vehicle models. Several vehicle models include three fixed scales which are representing the car-length, car-width, and height of cameras. Determination of positions of the four cameras can be presented in the form of matrix calculation of kinematics and motion variables as well as angle-sequenced graphics in the modeling of ghost view frames of the occupant configuration within the vehicle exterior system.

I reanalyze the surrounded monitoring not only for parking, but also for gathering real-time information for vehicle clusters in the city.

5.3.1 Introduction to Surrounded View Monitoring

Surrounded View Monitoring system includes screen that shows the environment around the vehicle at a glance 360 degrees. By using multiple wide-angle cameras to correct images shot in multiple directions in real time, correcting and converting distortion, combining them into a single image, and displaying them on the monitor in the vehicle as a bird's eye view 1) Can easily find out the location of its own vehicle and within a short time. This is because it is possible to objectively observe the location of a vehicle placed on a parking space as seen from the roof of a large building or from the sky. The image around the vehicle that is detected in real time through the parking assist camera can display the surrounding environment in 360 degrees within a delay under a millisecond within image recognition.

5.3.2 How Camera Works in the Vehicle

The method of mounting the parking assist camera on the vehicle is mainly selected by inserting it downward in the side-view mirror of the vehicle. In addition, thanks to the development of camera technology, a method of mounting on the door and a method of mounting on the body of the vehicle can be additionally configured.

5.4 Method

The method of mounting on the side-view mirror in the input of the camera can recognize the parking line drawn on the floor of the parking place without distortion. On the other hand, as an emerging method, the absolute position of the vehicle can be best selected by mounting the camera on the door of the vehicle. This is because the camera can be positioned near the physical center point of the vehicle within a battlefield of about 4 to 5 meters in the selection of the side camera attachment position. The physical center point of the vehicle is a point where half of the full width and the full length are located, and it is easy to assist the most stable parking when it coincides with the center point of the square for parking in the positioning guide as parking lot.

Setting with the short side as the x-axis, the long side as the y-axis, and the height axis as the (-)z-axis in the square plane of the parking lot from the perspective of looking at the vehicle parked in the sky as in the method. In a real vehicle, a study was conducted using a method of selecting the position of the camera by substituting the physical size in millimeters (mm) into a virtual space of pixel (px) size.

The location where the camera of the Surrounded View Monitor is installed inevitably conflicts with the exterior design of the vehicle lead by vehicle designer in prior specification. Choosing a location optimizing collision is a way to improve the emotional quality assurance of the car. In this study, one type of vehicle camera was selected, and the characteristics of the lens and the image processor constituting the vehicle camera were identified and used to simulate a virtual camera that could play the same role.

For automotive specification, the angle view necessary for the specifications of the vehicle's surrounded-view camera was satisfied in a manner suitable for the automotive electronics standard. For the camera setting, mass-produced sample part that can be mounted on a vehicle to form around view were utilized, and industrial specifications were applied to external temperature specifications like shown in Table 5.1 to 5.3.

5.4.1 Camera Setting in Real Vehicle

Table 5.1 represent the general specification of the vehicle camera installed.

Table 5.1: General Specification of the Camera Example

General	Setting Description of the Targeted Camera
Operating Voltage	5.5V ± 0.25V (Power supply from ECU)
Current Consumption	under MAX.100mA
Operating Temp.	-20℃ ∼ +70℃ (Industrial spec)
Storage Temp.	-30℃ ∼+75℃
Video Output	NTSC
Waterproof	IP67
Dimension	T.B.D ; 23.5(W) * 23.5(H) * 27(D), error under 5%
Waterproof	IP67
Exterior Material	Front Case : heat-resist ABS , Rear Case : ALDC
Weight	24g

Table 5.2 and 5.3 represent the lens and sensor specification of the vehicle camera installed. For the purpose of realizing vehicle environment, I structured the sensor with the spec of PC1030N* based on after-market product validation.

In order to apply the actual camera value to the virtual camera for simulation, the physical specifications of the lens were replaced with a lens constant with a calculated value. The viewing angle of the lens is basically 130 degrees vertically and 180 degrees horizontally, and was selected as a specification having the characteristics of a fish-eye lens that reflects an incident angle from the maximum horizontal range to 190 degrees.

5.4.2 Virtual Camera Setting

The virtual (replicated) camera setting is applied to a virtual space and a virtual screen so that the Around View can be configured on a PC instead of the screen inside

Table 5.2: Lens Specification of the Camera Example

Lens	Setting Description of the Targeted Lens
Focal Length	1.20mm ±5% (242.441 px in virtual lens)
Relative Aperture	2.0 ±5% 1/4” (2.7mm(V) x 3.6mm(H))
F NO.	2.0 ±5%
Angle Of View	130°(V) X 180°(H) (Max. 3.84mm : 190°)
Back Focal Length	3.0mm ±5% (FILTER & C/G)
Flange Back Length	1.83mm ±0.3
Optical Distortion	-95.00%
Chip Ray Angle(Max.)	7.87°
Relative Illumination	56.40%
Iris	Fixed
MTF : 1/4” (Center)	59.0% at 100lp/mm
(0.5f)	S:67.8%, T:64.5% at 100lp/mm
(0.7f)	S:73.4%, T:62.7% at 100lp/mm
(1.0f)	S:69.1%, T:50.9% at 100lp/mm
Lens Length	18.25mm ±0.3
Total Top Length	20.08mm ±0.4
Diameter (Thread)	M10 X P0.5
Head Size	¢18.0 - ¢20.0
Group & Elements	7 Glass (With IR Cut-off Filter : 650nm)
Coating	BBAR Coating
Function	Waterproof

Table 5.3: Sensor Specification of the Camera

Sensor	Setting Description of the Targeted Sensor: PC1030N*
Imager type	¼” CMOS Sensor (PC1030N*)
Resolution	minimum 300,000 pixel (640×480 VGA)
SNR	45.6 dB @ 60℃
Dynamic Range	63.5 dB @ 60℃

the vehicle. This is the table shows the minimum and recommended specifications for an operational system setup are as virtual camera.

Table 5.4: Minimum/Recommended System Requirement

Items	Minimum Specification	Recommended Specification
OS	Windows XP Pro SP3	Windows 10
HW	Xeon E5504 Dual+3GB RAM	Xeon Silver 4108 Dual+GPU+32GB RAM

The simulated camera is determined by the camera's internal parameter k and the correction constant d and by the distance r according to the following angle θ.

r$(\theta) = k_1\theta^1 + k_2\theta^3 + k_3\theta^5 + k_4\theta^7 + k_5\theta^9 = \sum_{i=1}^{5} k_i\theta^{(2i-1)}$

$\theta = \sum_{i=1}^{9} d_i x^i$

I replicated the virtual camera specifications like shown in Table 5.5 to 5.6.

Table 5.4 represent the general specification of the virtual camera replicated.

Table 5.5: General Specification of the Virtual Camera

General	Setting Description of the Virtual Camera (in pixel)
Video Output	NTSC
Dimension	T.B.D ; 23.5(W) * 23.5(H) * 27(D), error under 5%
Resolution	640x480 minimum 720x480 frequently used 2048x1536 available

In the virtual camera setup, the focal length of the lens is 242.441 px, which restores the focal length of the actual camera lens, which is 1.20mm ±5%, but the internal constant k is a (odd) polynomial order to see the maximum 190 degrees. The distance according to the angle was determined only by the odd order. The distortion correction constants d1 to d9 correct distortion of an image that may appear in the lens. It is used to correct the phenomenon that the entire image is concave due to distortion that curves toward the edge due to barrel distortion or pincushion distortion as it moves toward the edge from the center of the lens.

Table 5.6: Lens Specification of the Virtual Camera

Lens	Setting Description of the Virtual Camera
Focal Length	242.441 px (1.20mm ±5% in real lens)
카메라 내부상수 m_u/m_v	271.04/239.20 (no unit)
optical center of lens c_x/c_y	356.66/234.44 (no unit)
	$k_1 = 0.894$
	$k_2 = -0.0046$
	$k_3 = 0.0056$
	$k_4 = -0.0054$
camera's internal parameter k	$k_5 = 0.0011$
$r(\theta) = \sum_{i=1}^{5} k_i \theta^{(2i-1)}$	$d_1 = -0.0000099$
	$d_2 = 1.118$
	$d_3 = -0.0094$
	$d_4 = 0.067$
	$d_5 = -0.198$
	$d_6 = 0.353$
	$d_7 = -0.380$
	$d_8 = 0.228$
camera correction constant d	$d_9 = -0.056$

The cx/cy (optical center), the center of gravity, restored the center of the actual lens to 356.7 and 234.3 from the maximum resolution of 720,480 on the virtual image. Instead of aligning to the center due to the manufacturing technical limitations of the camera by placing a slight deviation in the center of the virtual screen, the error measured by software is corrected.

(mu, mv) $\propto (fx, fy)$

is a constant inside the camera, which is a value that corrects the generalized image plane of the distance vector from the center point.

The point Xw=(xw, yw, zw) on the entire coordinate is projected as a line Xc=(lambda*xc, lambda*yc, lambda)=RXw+T consisting of points on the image plane, which is the point on the image coordinate (u, v)=(u0+muxc, v0+muyc). Here, (cx, cy) is the image center coinciding with the center of the optical axis of the camera, and (mu, mv) is the focal length.

The simulator for the virtual camera for simulation receives an arbitrary location of the camera and synthesizes a screen shot by the virtual camera at the location into an around view image.

5.5 Experiment for Vehicles

In order to synthesize the surrounded view image, it is necessary to acquire a random image according to the camera mounting position mounted on the vehicle, but it is difficult to measure the camera position and posture. As a solution, I developed/used a virtual camera simulator that can generate a perspective view according to an arbitrary camera position by calculating the internal constant and lens distortion model constant by adjusting the initial value of the camera.

The virtual space is defined as a space surrounded by five planes. The five planes are composed of the bottom plane, the front plane, the left plane, the right plane, and the rear plane, and a pattern can be put in each plane. The size of each plane is designed to be variable, and at this time, the four planes except the floor plane are input to have a constant height.

The caption of the figure should be located below the figure and end with '.'

This section shows how to insert your figures in your thesis.

In the actual program, each plane is defined by using a patterned image. The pattern on the image represents the texture of each plane, and the texture of each plane is mapped to the camera image. In order to grasp the relative origin of the actual vehicle position, the markers in the form of a cross can be placed on the four walls, which are the background of the Around View, in the form of a grid to determine and adjust the position of the vehicle in grid units.

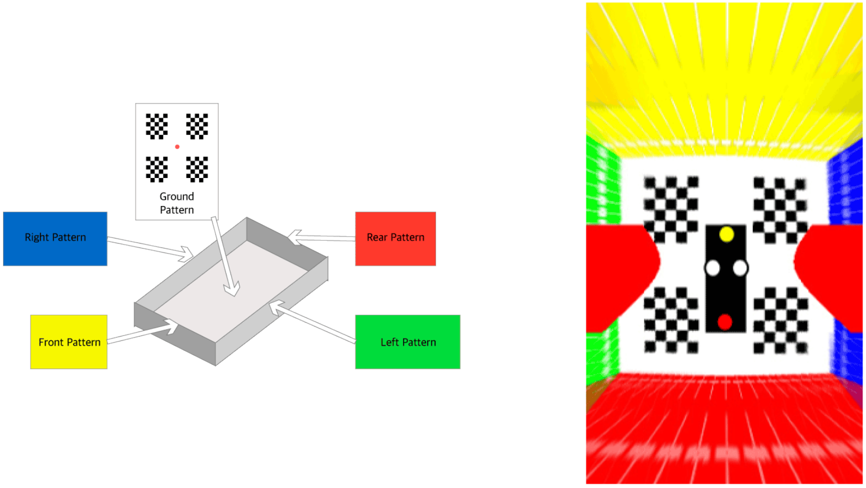


Figure 5.4: Example 1.

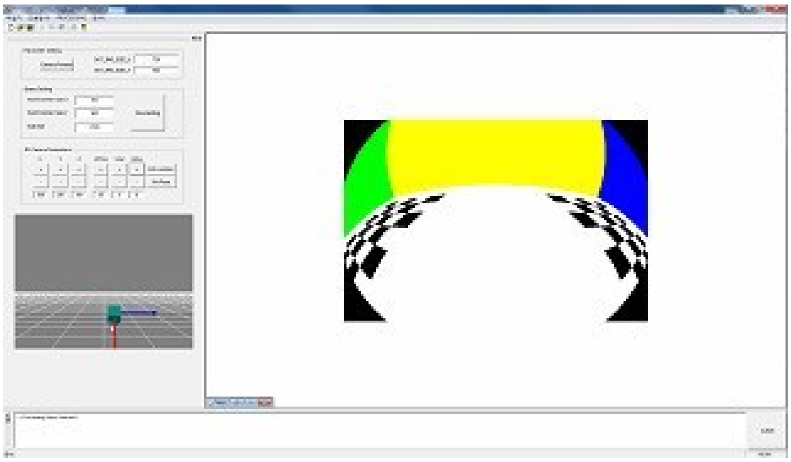


Figure 5.5: Setting a virtual front camera by using simulation tool.

5.5.1 Camera Positioning

In this study, the manipulator structure was constructed based on the case of mounting the camera position on the bottom of the side view mirror. The reason why the bottom of the side view mirror was selected as the mounting position in the initial stage is that global automakers are mounting Surrounded View cameras at the bottom of the side view mirror to verify various possibilities and proceed with mass production. Accordingly, the composition of the cameras for surrounded views can be applied to mount on the body extension of a vehicle such as a door or C-pilla, etc.

This section shows how to insert your figures in your thesis.

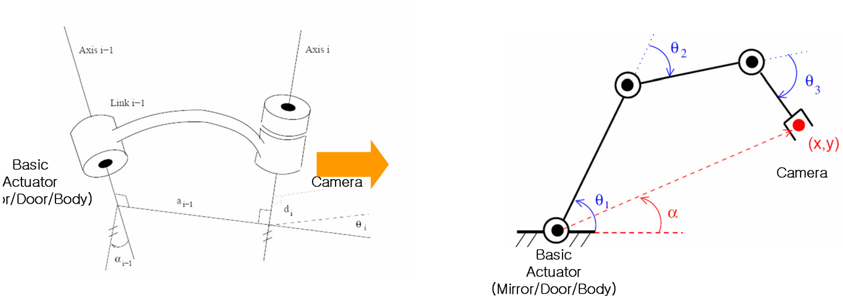


Figure 5.6: Example 1.

Manipulator is a mechanical structure that is connected by a rigid link and a joint, and is an artificial mechanical structure that can control anti-freedom movement in the positioning of the camera. The area requiring parallel movement is composed of a prismatic joint, and the area requiring rotation consists of a revolute joint. The structure can be controlled and controlled by the movement of the joint.

For the camera positioning, the contact point of the camera lens is regarded as the end-effector of the camera role, and the final spherical (r, θ, ϕ)

coordinates of the end-effector are obtained and converted into Cartesian: (X, Y, Z) coordinates. Kinematics is a computational method that deals with the relationship

Table 5.7: Kinematics for the manipulator of the side view mirror

#	Manipulator Structure	Representation	Example in the research
0	Orientation	Base	Plane joint with vehicle body
1	Joint Position #1	Joint1	X axis of the camera
2	Joint Position #2	Joint2	Y axis of the camera
3	End-effectors Position	Tip	Lens of camera

between a manipulator and an end-effector. In this section, the Around View camera is divided into front/left/right/rear, and is composed of each manipulator and coordinates are extracted through kinematics.

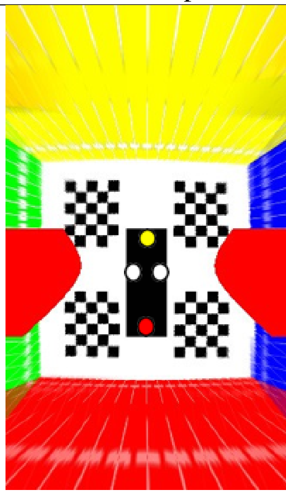
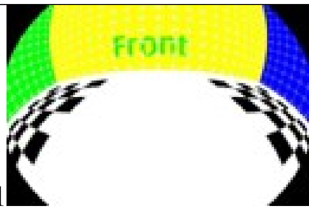
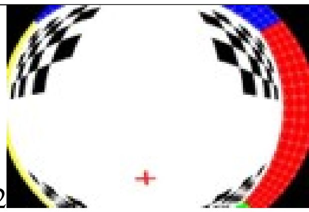
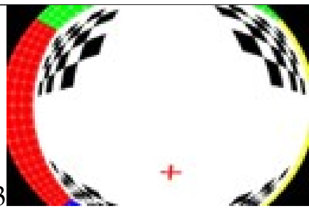
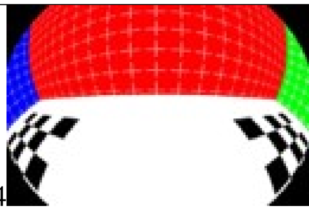
5.5.2 Experiment Design

As a result of analyzing the G model of H company currently released in Korea and reading the position of the camera using a 3D scanner, the position coordinates (x,y,z) and rotation angle of the camera in each direction of Front, Right, Left, Rear (xR, yR, zR). To reconstruct the position and rotation angle of the extracted camera, it was changed to virtual coordinates. How to change the width, length, and height of each 1000px, 1000px, 1500px in a 3D virtual space (0,0,0,1000,1000,-1500), the actual vehicle's full width, overall length, height, and camera mounting position 10mm Conversion was performed by reducing the ratio to a ratio of 1px.

At this time, the average point of the positions of the left and right cameras was projected onto the ground (500,500,0), and the images appearing from the virtual point of view of each image recognized on the screen according to the position of the camera were expressed on the simulator screen. . The results of analysis of H company's G model with a simulator are shown in the following position and screen simulation of front and rear cameras

By calculating the manipulator Kinematics (Width, Length, Height, Height of the side view mirror end effector), the values can be configured as (yb-yf, xr-xl, vehicle height, zr) respectively. If the size of the image plane is set to (1000 x 1000 px), and

Table 5.8: Camera Installation and Display Simulation of the Comparative Vehicle

Comparative Vehicle (unit: mm) Length: 4910 Depth: 1860 Height: 1470 Height of side view mirror end effector : 986							
Camera	x	y	z	x_R	y_R	z_R	
Front CAM	500	330	-69	55	0	0	1 
Right CAM	601	500	-99	0	+8	90	2 
Left CAM	409	500	-99	0	-8	-90	3 
Rear CAM	495	801	-91	58	0	180	4 

the center point (500,500) is selected as the center point of both sideview mirrors, each of the four cameras will capture the base end-effector based on the (0,0) point. A total of four points can be displayed. On the other hand, on the z-axis, the value is the same as zr=zl. Based on the height of the front height, the height value for each candidate location at the camera mounting position was measured and displayed in the z-coordinate as the proportional distribution of the same pixels.

The simulator of the comparison vehicle model outputs the image appearing from the perspective of the image recognized on each screen on the front/left/back/right side in the clockwise direction to the simulator screen, and when it is synthesized as an around view screen, it becomes an around view monitor screen.

For the experiment, the method of finding each candidate location to calculate the coordinates of the virtual space required by the vehicle's Around View monitor for each vehicle model and the other two vehicle models, respectively, is calculated as follows: Proceeded as follows.

5.6 Result: Calculation for Camera Position Selection Based on Comparison Group Specifications

The procedure of substituting the proportional expression comparing the specifications to the manipulator Kinematics formula to select the location of the Surrounded View camera by using the lower side view mirror as in the comparative vehicle is for the vehicle 1 and vehicle 2.

1) The first joint and the first angle of the Around View Camera are the angles of the Base Actuator, which is the same as the mounting angle of the Side View Mirror. Therefore, θ1 is the side view mirror mounting angle. 2) The second joint measures the L1, the length of the link, by determining the possible position on the exterior design where the camera can be attached, and determines the angle of attachment of the link and camera to the virtual link of the same length as θ2. 3) Since the camera angle

must be mounted on the vehicle and meet the criteria for viewing angles in the Around View, the (Height of the sideview mirror of the experimental vehicle)/(Height of the sideview mirror of the comparative vehicle) proportional to the shooting range of the comparative vehicle Obtain the field of view by multiplying the width of sin($130^{o}/2$)x floor for half ($130^{o}/2$) of the lateral camera shortening projection angle. At this time, the height limit of the side camera can be obtained so that the image projected on the front camera overlaps the image of the side camera.

5.6.1 Evaluation

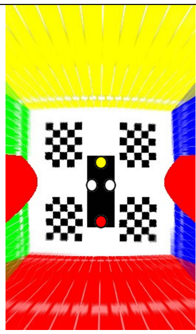
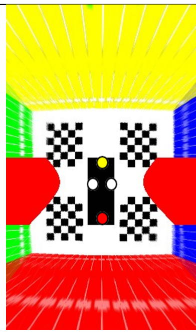
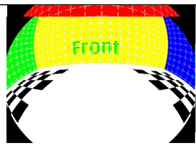
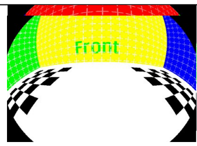
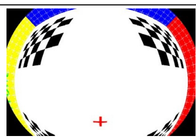
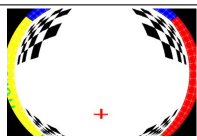
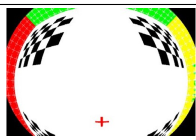
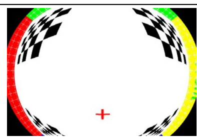
As a result of simulation of the virtual camera, it was confirmed that a normal around view screen was derived. The following contents could be verified through simulation. 1) If the Around View camera can correctly calculate the mounting position and mounting angle, it can be successfully configured to show the Around View even if there is a difference in the physical size of the vehicle within the range of the comparison group and the experimental group. 2) Manipulator Kinematics can be calculated to adjust the camera's mounting position and mounting angle to extract the location where around-view shooting can be achieved within the limitations of the external design. 3) Even if the camera is mounted with camera specifications such as front/rear/left/right within the physical range where the camera angle can be adjusted, the camera can be configured so that the images projected on the front and rear cameras are synthesized with the images on the side cameras to form an around view. Common use can be utilized. 4) For verification of the contents confirmed through the experiment results, the location where the vehicle was equipped with the Around View was restored, and the actual camera of the same specification was directly mounted and the Around View was taken. With the same specifications as the screen presented in the simulation, the camera was shot directly at the corresponding location to form an around view.

As a result of shooting in the front/left/back/right direction, it was confirmed that

Table 5.9: Camera Installation and Display Simulation of the Comparative Vehicle

<table>
<tr><td colspan="7">Comparative Vehicle #1/#2

(unit: mm)
#1
Length: 4845 Depth: 1835
Height: 1455
Height of side view mirror end effector : 1023

#2
Length: 4530 Depth: 1775
Height: 1460
Height of side view mirror end effector : 924</td><td></td><td></td></tr>
<tr><td>Camera</td><td>x</td><td>y</td><td>z</td><td>x_R</td><td>y_R</td><td>z_R</td><td>#1</td><td>#2</td></tr>
<tr><td>#1 Front</td><td>500</td><td>318</td><td>-66</td><td>61</td><td>0</td><td>0</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>#2 Front</td><td>500</td><td>343</td><td>-75</td><td>60</td><td>0</td><td>0</td></tr>
<tr><td>#1 Right</td><td>587</td><td>500</td><td>-100</td><td>+9</td><td>0</td><td>90</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>#2 Right</td><td>584</td><td>500</td><td>-92</td><td>0</td><td>0</td><td>90</td></tr>
<tr><td>#1 Left</td><td>413</td><td>500</td><td>-100</td><td>+9</td><td>0</td><td>-90</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>#2 Left</td><td>416</td><td>500</td><td>-92</td><td>0</td><td>0</td><td>-90</td></tr>
<tr><td>#1 Rear</td><td>500</td><td>802</td><td>-91</td><td>54</td><td>0</td><td>0</td><td rowspan="2">Protected image</td><td rowspan="2">Protected image</td></tr>
<tr><td>#2 Rear</td><td>500</td><td>796</td><td>-91</td><td>60</td><td>0</td><td>180</td></tr>
</table>

the actual camera can provide the correct image at the mounting position. It was confirmed that the composition of the Around View screen can be normally synthesized by applying the calculated values of the virtual camera coordinates of a single camera specification.

5.7 Reflection

In this study, according to the specifications of different vehicles, the positions of four cameras for around-view monitoring were calculated by kinematics transformation. In addition to the existing comparison group, experiments were conducted to install the Around View Camera on two new types of vehicles. Through the analysis result in the 3D coordinates, it was confirmed that even if the vehicle specifications change, it is possible to construct an Around View using only one camera of the same type for vehicles of different sizes within a small difference. In addition, it was confirmed that the virtual around view was successfully formed by inputting the data derived from the calculation into the simulator. Although there are differences in the diversity that is configured according to the specifications of the vehicle, a method has been established to properly reconstruct and utilize a high-performance camera from a common platform in a variety of vehicle types, so an expansion and configuration method for each vehicle type is required. In the future, the position of the manipulator is calculated by kinematics even when a model that physically changes the size of the existing model or when a new model is released, even within the limits of using the same type of camera.

The summary of the series of conclusions is as follows. 1) Surround view screen on the front/back/left/right side with the same camera specifications can combine them to one around-view. 2) Virtual shooting can be performed using a virtual camera that has the same effect as a real camera specification. 3) When shooting a virtual camera, the manipulator Kinematics can select the proper location for the camera. 4) It is possible to construct a parking assist system that can reduce fuel consumption by applying an appropriate position of a virtual camera to a real vehicle.

5.8 Application of Surrounded View to Vision Sharing among Clustered Vehicles

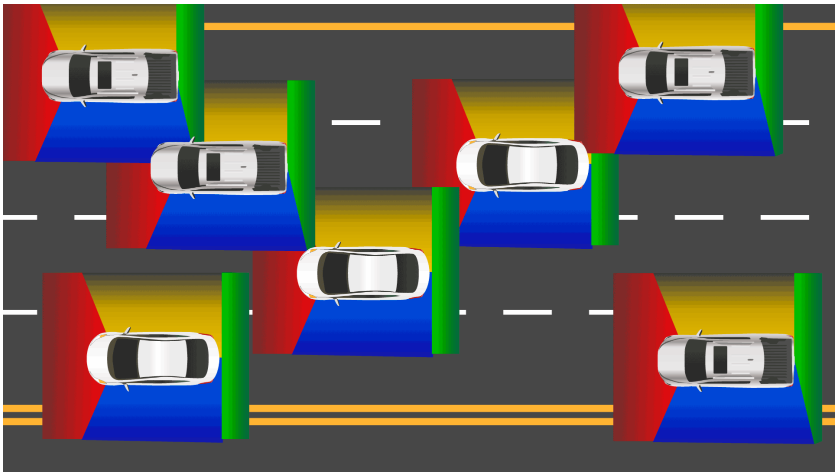


Figure 5.7: Example 1.

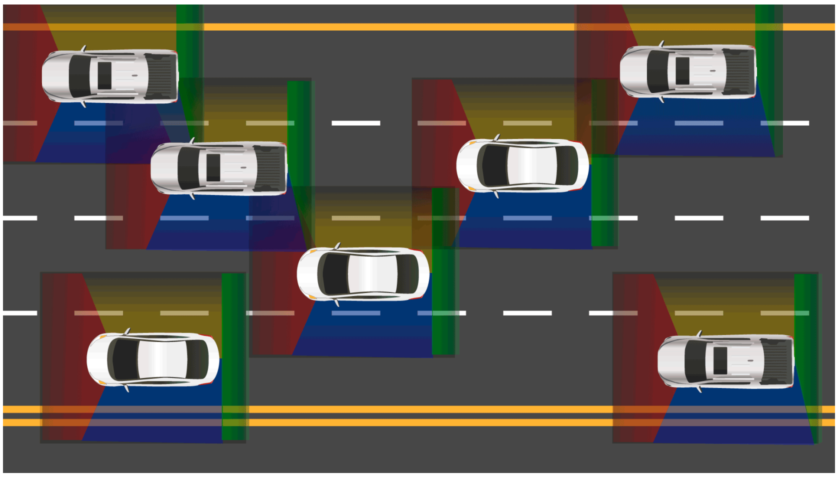


Figure 5.8: Example 2.

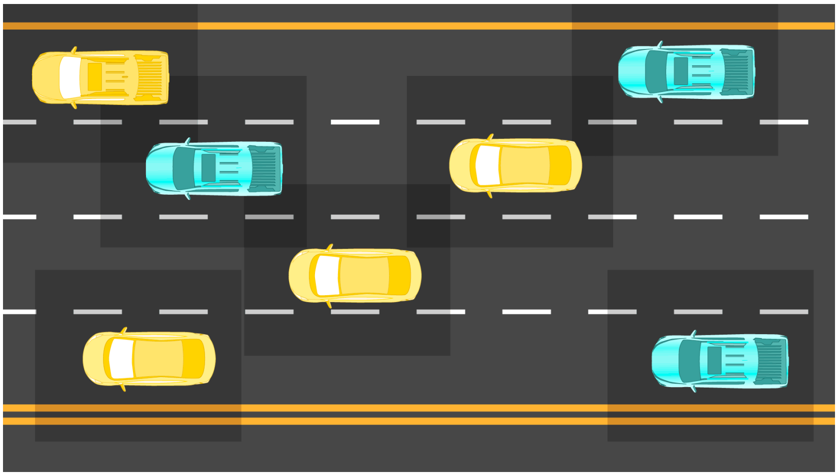
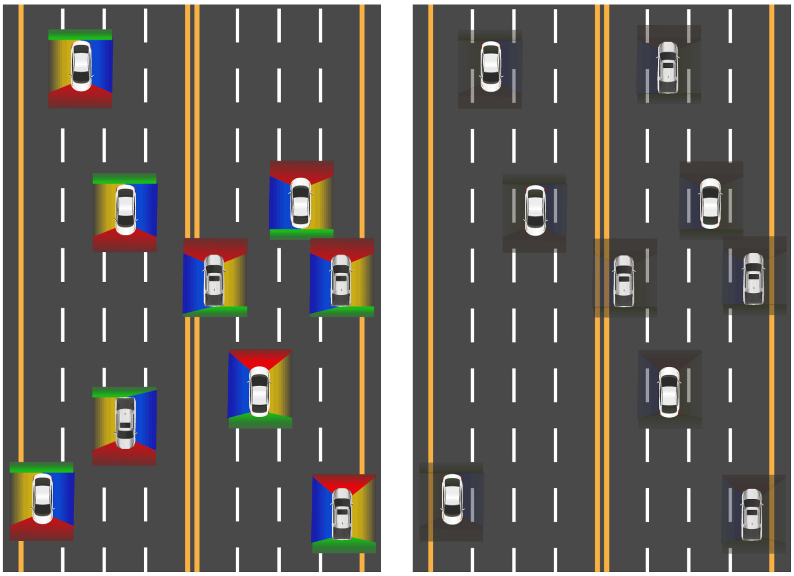


Figure 5.9: Example 3.



21.7% lanes area on capturing.

In this section, illustration on expendable parts journey recorded by context-aware camera is described with smart tracker for parts delivery logistics and lifecycle management. It is implemented within hyperledger based blockchain database.

5.9 Section Example

This is section example.

5.9.1 Subsection Example

This is subsection example.

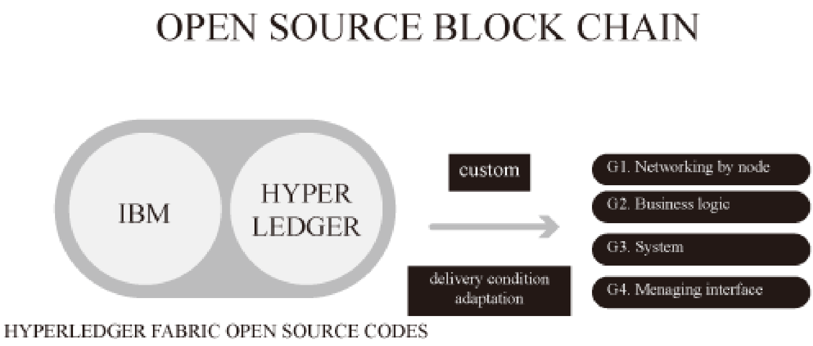


Figure 5.10: ***

%endfigure

Transportation authorities and car manufacturers have compiled more information regarding car accidents. There has been increasing interest in using these car driving logs to predict and prevent car accidents that occur in the highways and roads. Still, mobility research has focused primarily on vehicle dynamics rather than design for drivers and users.

I focused this case study mainly on user experience. This research aims to propose multiple access point robots along highways and roads to safely and conveniently

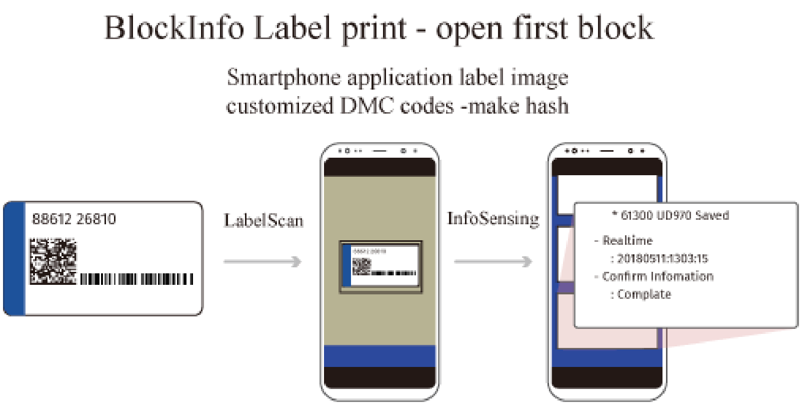


Figure 5.11: ***

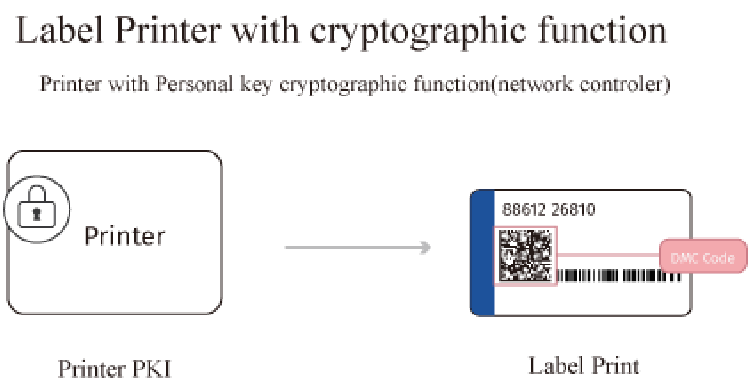


Figure 5.12: ***

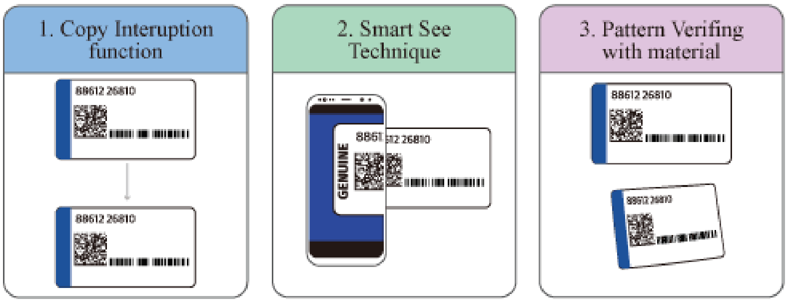


Figure 5.13: ***

Manufecturer	D.C.	Delivery	Agent	Customer	Agreement result
O	O	O	O	O	Original Parts
O	X	X	X	X	Gray market Parts
X	X	X	X	X	Imitation Parts

Figure 5.14: ***

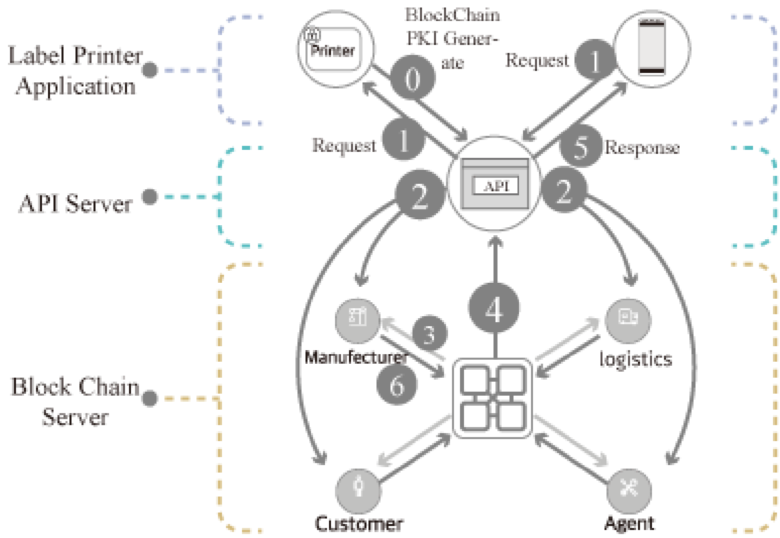


Figure 5.15: ***

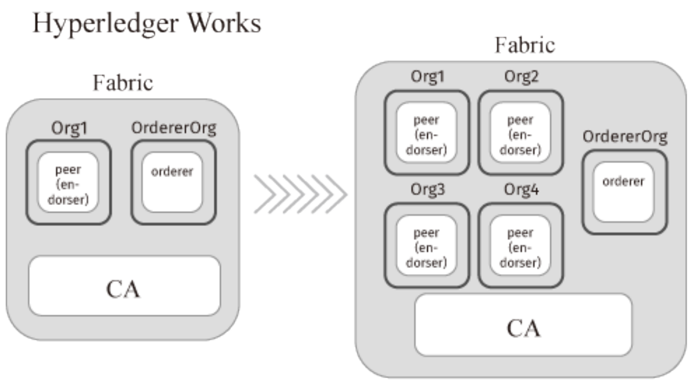


Figure 5.16: ***

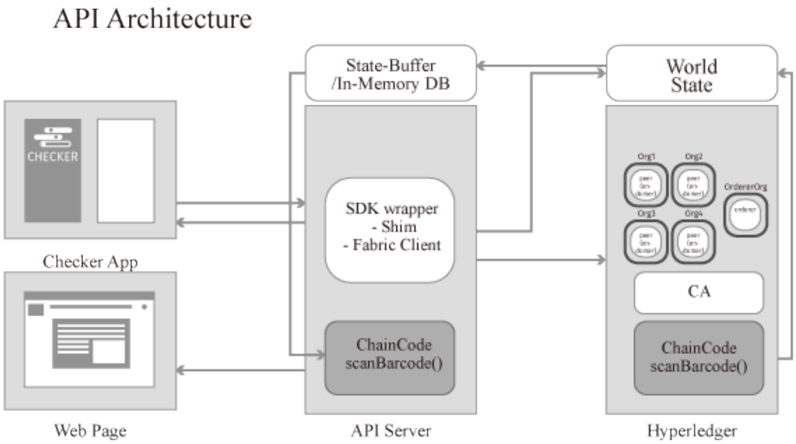


Figure 5.17: ***

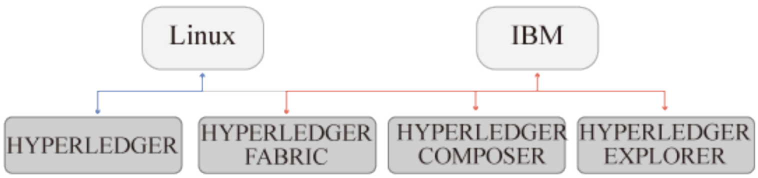


Figure 5.18: ***

Figure 5.19: ***

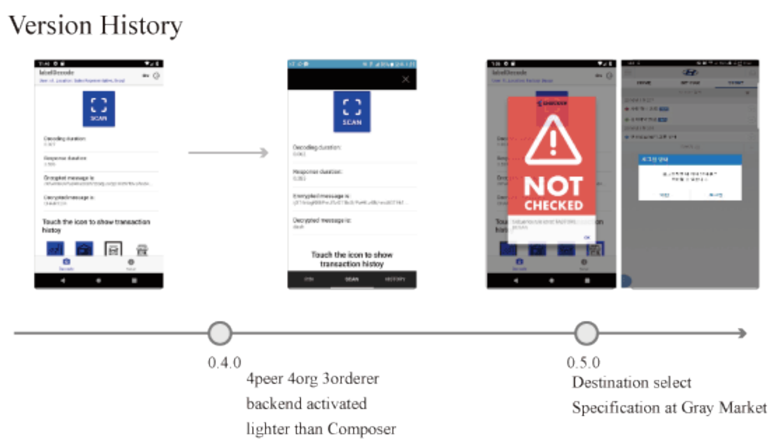


Figure 5.20: ***

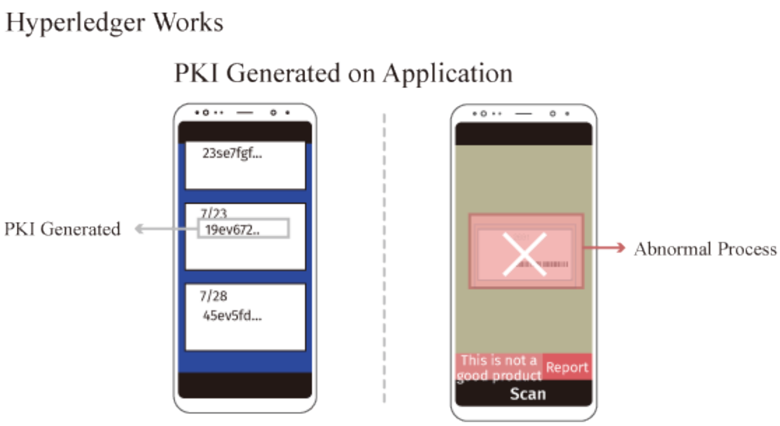


Figure 5.21: ***

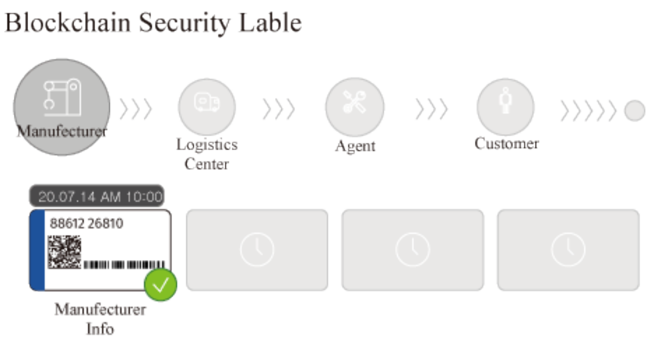
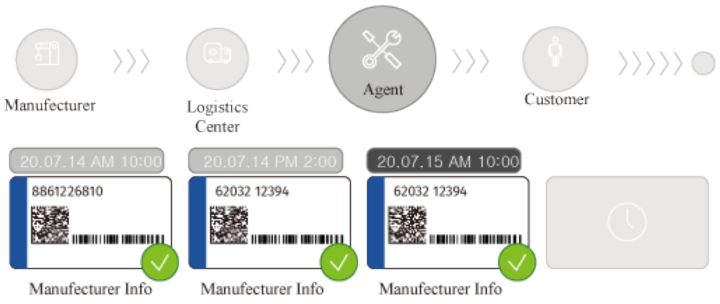


Figure 5.22: ***

Figure 5.23: ***



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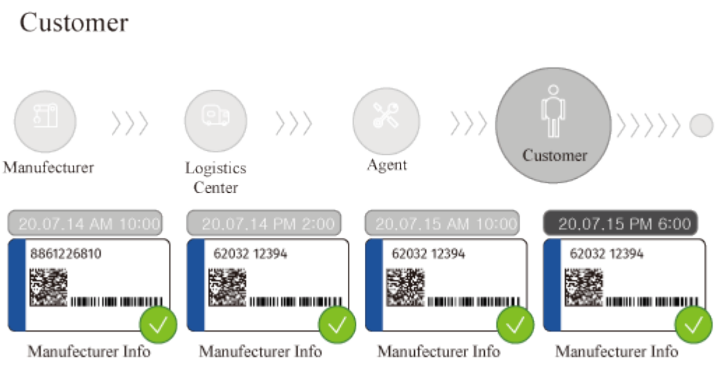


Figure 5.25: ***

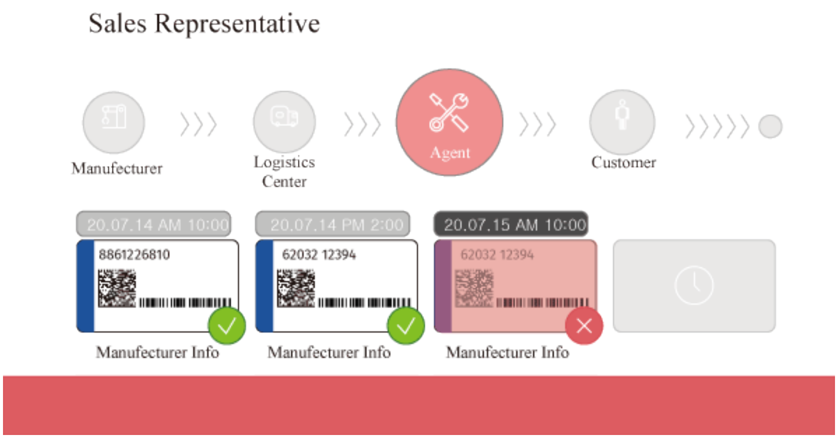


Figure 5.26: ***

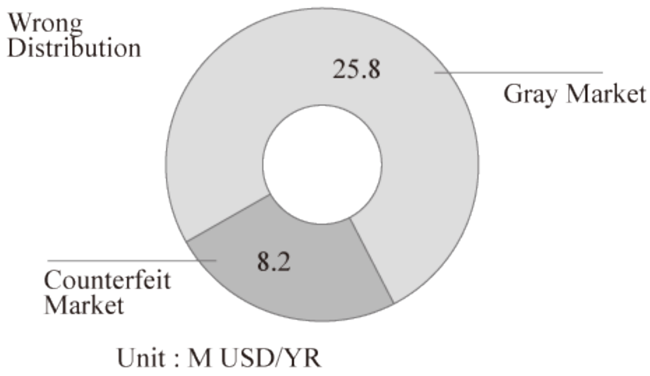


Figure 5.27: Problem information example of the wrong parts distribution worldwide

Manufec-turer	D.C.	Delivery	Agent	Customer	Agreement result
O	O	O	O	O	Original Parts
O	O	O	O	×	Already Opened
O	O	O	×	×	Gray market Parts
O	O	×	×	×	Gray market Parts
×	×	×	×	×	Counterfeit Products

Figure 5.28: Stage of delivery in vehicle parts distribution

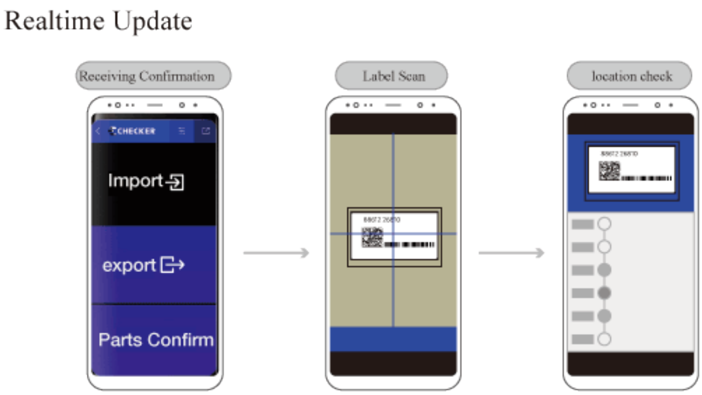


Figure 5.29: Mechanism of camera based QR scan to track the vehicle parts

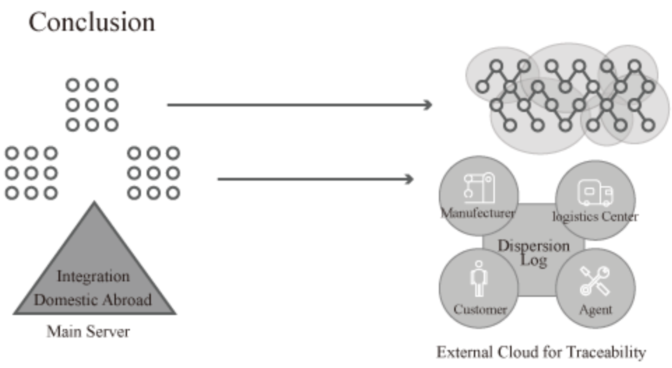


Figure 5.30: Decentralization of vehicle parts tracking platform.

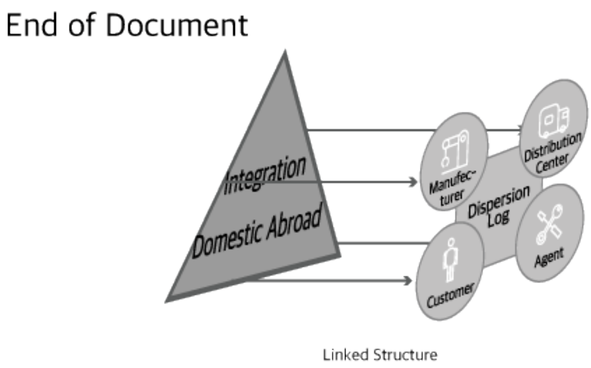


Figure 5.31: Network decentralized on peer by peer.

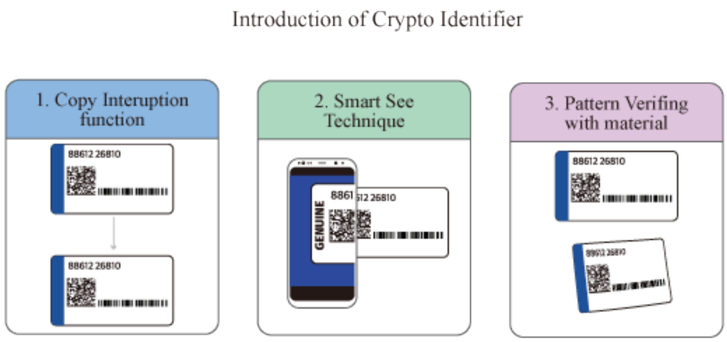


Figure 5.32: QR mark overlay image identifier for vehicle parts label

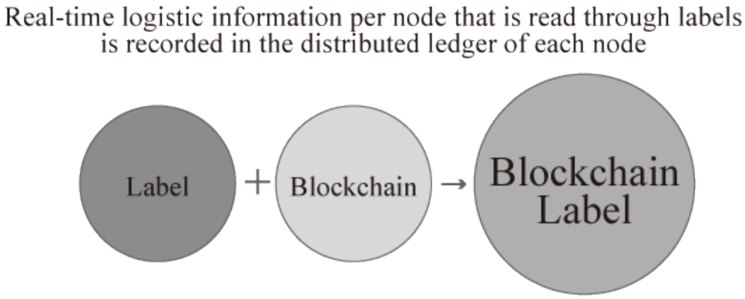


Figure 5.33: ***

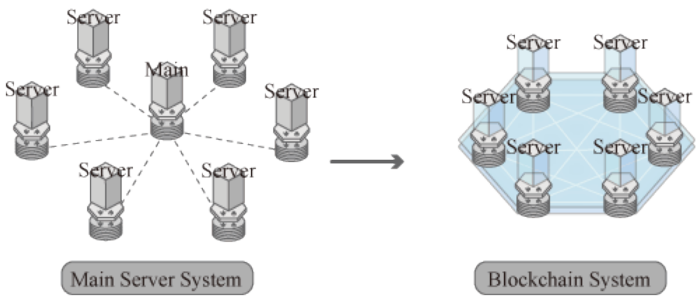


Figure 5.34: ***

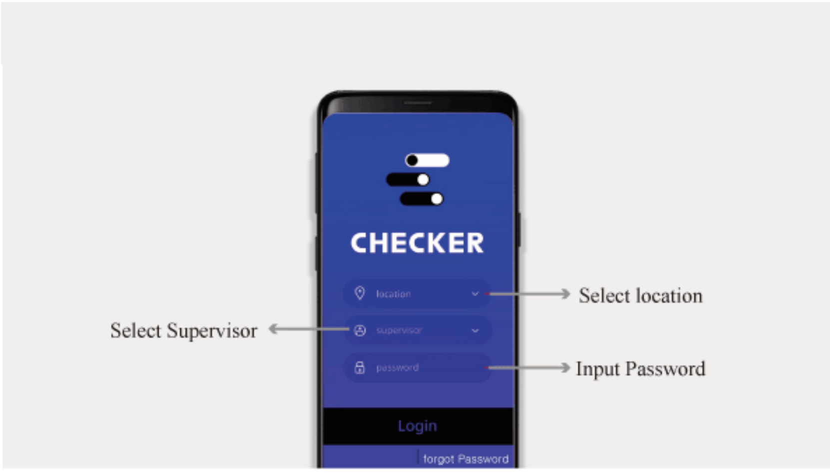
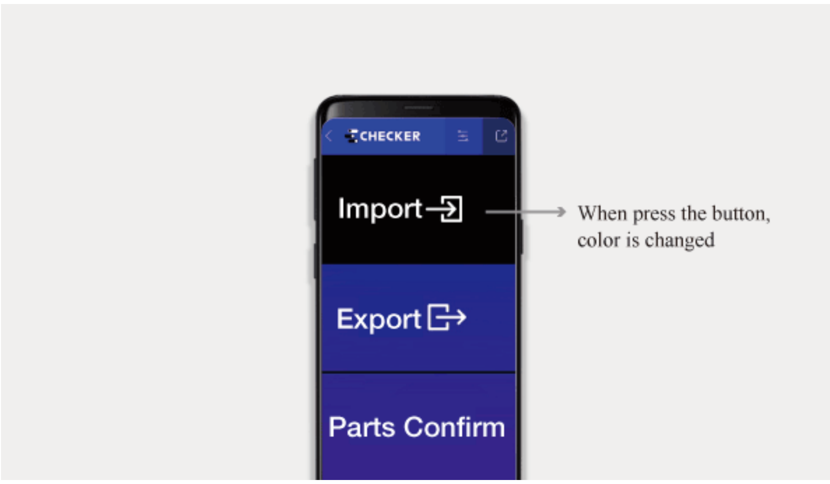


Figure 5.35: ***



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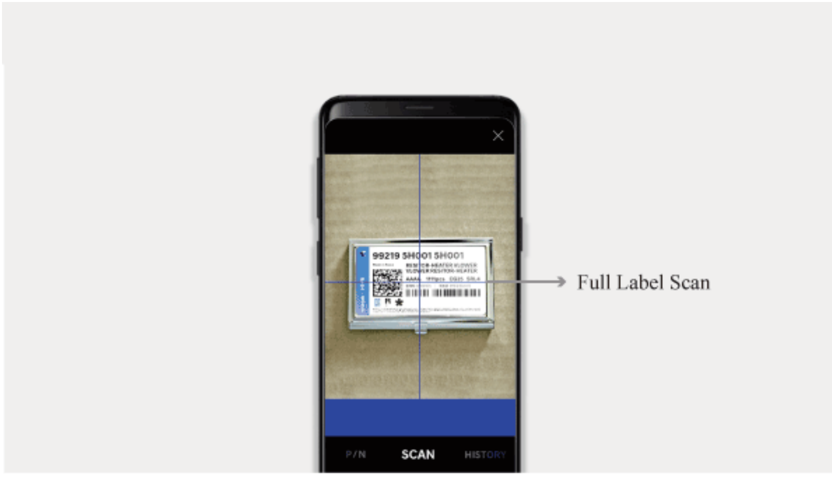

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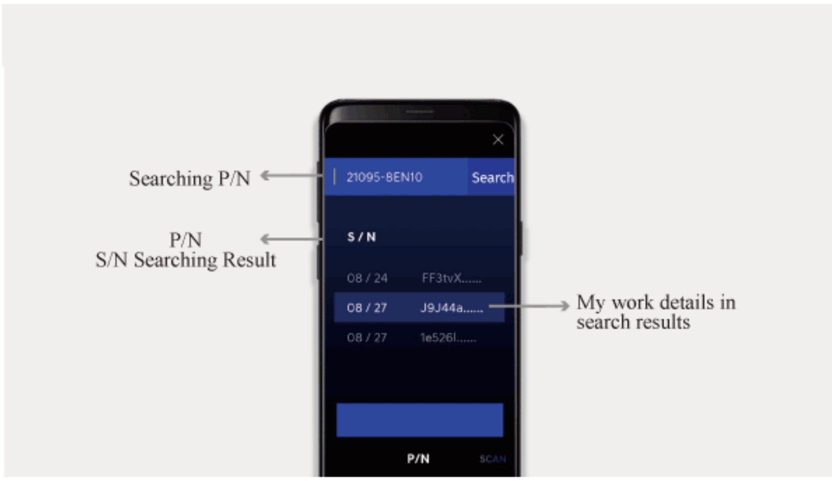


Figure 5.38: ***

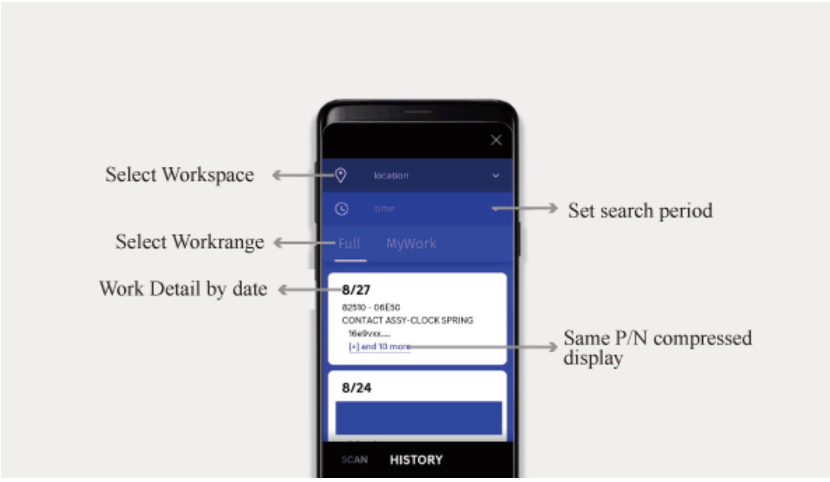


Figure 5.39: ***

Figure 5.40: ***

Figure 5.41: Delivery tracking status with parts information at the mobile app

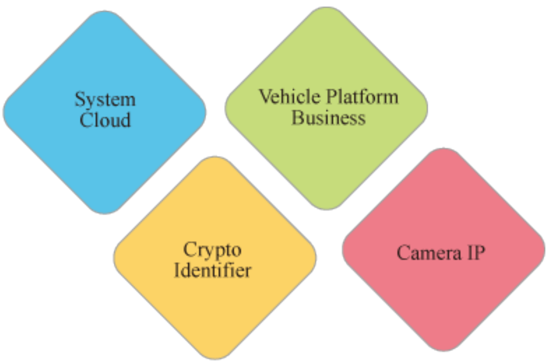
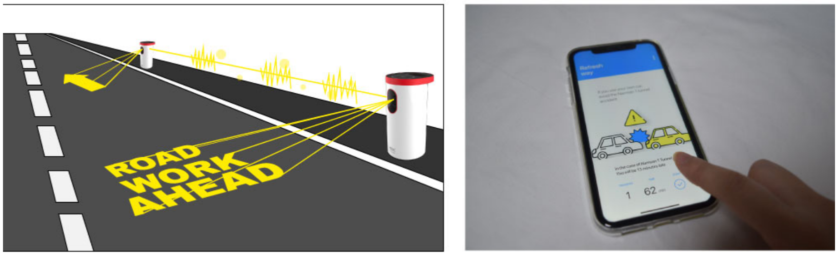


Figure 5.42: Intellectual properties included in the delivery tracking data generation



(a) (b)

Figure 5.43: Chapter8: research on the sensor robot and the mobile app: (a) first draft version of a safety sensor function module for robot communication, adapted from [3]; (b) our mobile app that provides information on route conditions.

provide useful information for users. The real-time communicative sensor robot system provides users with information on detours from busy roads to prevent secondary vehicle accidents [3] or allows them to select alternatives among other transportation modes in their enhanced experience. For these purposes, mobile applications (apps) simultaneously connected with open application program interfaces (APIs) become useful for providing information.

Figure 8.1 shows the initial draft of a safety lighting device that generates a relatively narrow, intense light beam to prevent car accidents while driving at near and distanced places. The objective of the current research is to enable the driver to determine the bypass path and be guided into that path promptly. In addition, I aim to efficiently communicate to the driver that the road is hazardous. If a road is nonfunctional, the information first flows from the sensor robot to other robots to represent the message and finally to the cloud network of the database [6]. From the database, the application programming interface (API) transfers the log message to users' mobile phones per their customized settings.

This section describes a convergence project of infrastructure from robot and application software "Today's commute" based on public API. A group of sensor robot devices that are designed for the highway/road environment have to communicate together effectively for providing information to more users. They can send transactions via TCP-IP in a wireless environment (e.g., ad-hoc network among sensor robots.) Communication is ensured through APIs and widespread networks. To support data distribution, these nodes are linked together and operate collaboratively.

The object of this section is designing of new vehicle-to-vehicle, vehicle-to-infra, infra-to-infra, communication system working in mobile to support safety for vehicles around with their examples. As the result, groups of safety infra devices induce a variety of vehicles on a bypass route, as vehicle safety guidance method and its systems method using the same method.

Causality is prevalent in scientific and philosophical research; for example, how effective a policy was for efficient utility, how effective medicine (treatment) was for lung cancer, which advertisement (treatment) would give the highest click are for a given client (AB-testing). Causal inference in statistics interprets the abovementioned questions as ones inferring the effect of a given treatment in the data generating process. Causal inference has been used in the technology industry, public health, and economics; in addition, it has received recent attention as a tool for data-driven decision-making processes. A considerable amount of research has been conducted regarding road safety with causality [8,9]. Many traffic data are observational, rather than experimental; this makes causal inference applicable.

For determining whether or not certain factors have any effect in reducing road traffic crashes, most published papers have used regression models with simulated [2] or observational data [10]. Low pavement marking visibility has been shown to increase the rate of accidents at night, compared to during the day, by the two popular methods: potential outcomes and causal diagrams frameworks. In road safety, data are restricted to that of drivers and vehicles involved in road accidents. For solving the selection bias problem, responsibility analysis is implemented to evaluate the effect of a given factor on the risk of an accident.

Swarm robots, including sensors that emit safety lights, collect their information from ad-hoc networks to make it easier for commuters to drive easily or not to drive. Representation of the robot interaction is transferred directly face-to-face for vehicles nearby, and through the mobile app for distant driver users.

To interact with the sign systems and for the driver to have a contextual [10] knowledge, I need a technique that can solve the problems mentioned above. From a construction area, an automated behavior system can disclose the location of a traffic guide mannequin robot device. HoIver, this system still does not identify the dangerous regions of the road. To identify the safe parts of the road and to manage the risk of high accident/fatality [11] rates, worker/driver safety measures should be implemented on roads. It is necessary to:

First, improving the visibility of the information that the driver needs to identify the bypass path when it is necessary to guide the vehicle to the bypass path at night.

Second, increasing the level of safety and accident prevention policies during road management. Third, informing the driver of the detour route efficiently so they can safely bypass unusable roads and avoid unavailable roads.

When a device [3] guides a vehicle to a bypass path, it is possible to efficiently inform the driver of the vehicle that the road is in an unusable state.

Real-time path exploration is needed for analyzing the road situations, such as car accidents, status of road pavement, and black ice zones because of Iather, and alternative suggestions (pathway/route) for users who are not on the road. Road safety apps should including ”Simulation of real-time path exploration”, ”Traffic congestion indication”, ”Representing alternate options, including selection of customized path”.

Customized pathfinding in networks can share information not only to drivers' vehicle guidance but also to public transport information services. In the research on drivers from greater Seoul metropolitan areas [18], selecting options of driving and public and customized paths Ire major concerns influencing users.

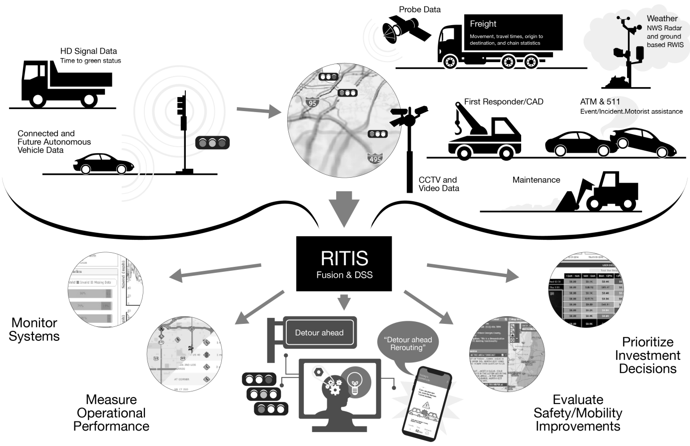


Figure 5.44: The Regional Integrated Transportation Information System (RITIS: https://ritis.org/) integrates existing public/private data.

Regional Integrated Transportation Information System (RITIS) [19] shows the convergence of information that can influence road safety. A database of public infrastructure and third-party data is one way of improving transportation efficiency, security, and safety [20] via the integration of data. The collected data are interlocked with the application and secures stability.

The RITIS platform [19,20] has a detailed query builder within EVC (Exploring and Visualizing Crashes) that enables users to generate complex queries in real-time depending on causality using data: crash accident type, damage receipt, lighting condition, vehicle type, age, gender, injury type, received location, date range, collision type, and damage type, which is drug/alcohol-related. Impact and causality analysis are the final objectives of the archived operational data analysis. Impact analysis provides a more hidden observation of observations (e.g., last Iek's heavy snow caused significant delays in the region). In addition, the government officials can use other analysis tools found within the RITIS platform to review the safety data of police accident reports or Advanced Traffic Management System (ATMS) incident/incident reports to determine if there are accident hot spots that could have a global impact on road congestion. Some of these tools make deep query and causality analysis possible.

NJDOT [21] combines archived operational data with data processing and visualization tools to identify performance problems in transport systems and develop easy-to-understand performance measures through visualization; this is consistent with senior leadership, elected officials and the public. It helps decision makers by providing them with the ability to automatically detect and rank the worst bottlenecks across counties or states, determine causality, determine whether congestion is repeated, measure economic impact, and create graphics that can be inserted in pairs of analysis documents. Once the user determines when and where congestion occurs, additional tool overlays (e.g., construction, accidents, special events) can be selected to place data on the time vortex to identify event causalities.

Based on the connectivity betIen the infrastructure and mobile devices [22], the "Vehicle Guidance Network" began with the need for classifying traffic jams and enabling AI-driven problem solving to improve driver commutes. For both drivers and public transport users, a safety sensor robot was designed to act as a guidance system for urban commuters. Requirements and needs to develop the guidance system can be extracted from the series of design processes described below.

The prototype was structured to get information from the robots in network. Each process includes the planning, data collection, idea sketching and prototype stages, and the prototype that repeats modifications.

I observed and interviewed several commuters with the method of town-watching and in-depth interviews (IDI). As shown in Table 1, the purpose of this observation is to identify inconveniences caused by a lack of information during the commute. As the observations Ire aimed at finding/creating [25] ways to improve the information, I also observed the flow of behaviors that led to decision making by the commuter. A contextual interview was conducted to find the hidden inconveniences that participants felt during the morning commute. I inquired about the reasons that led to particular driving decisions in their daily commute schedule.

Through the observation and context interviews, I Ire able to identify various types

Figure 5.45: Example 1.

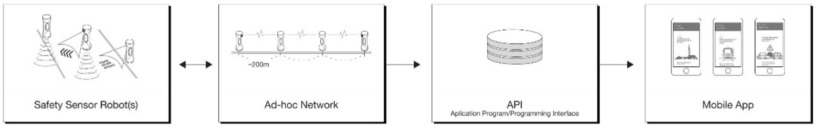


Figure 5.46: Example 1.

of incidents faced by drivers on their way to work, as shown in Figure 5. In the event of a road accident, the involved drivers and their vehicles are held up until the insurance company gets to the accident scene, resulting in a traffic bottleneck. Distant drivers should be informed to bypass such risky paths via a channel (e.g., mobile app) through the vehicle guidance system network. I could find, discover, and recognize a partial structure [25] of the network by exploring such problem spaces.

According to the affinity diagram of Figure 8.5, I categorized vehicle drivers into four groups (upcoming, entered the road in issue, on the accident road, already in an accident) with the arrangement of the user journey map belonging to the four groups of drivers, in the right side. The affinity map identified the needs of users. First, rare data Ire positioned along the axis of feasibility and driver's needs, and the necessity for two products (robot/app) was derived based on the time and the distance from the road where the accident occurred. The key insight extracted from these figures is that drivers near and distant from a car accident area require different solutions.

Table 5.10: User observation research with interview

	Goal	Observation Details
Observation	**To identify inconvenience:** caused by ignorance of road conditions in the morning rush hour and to find ways to improve road	**Observe the behavioral fl** of decision-making in th participant's morning sche
Interview	**Contextually to identify hidden inconveniences:** that participants experience in the morning rush hour	**Ask participants about the r** that influence driving decis during the morning comm

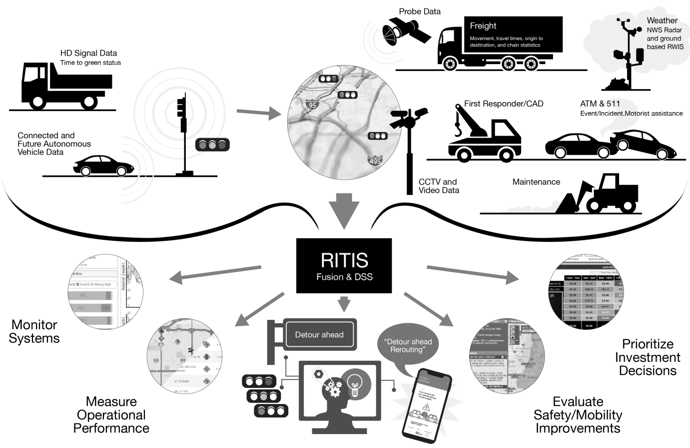


Figure 5.47: Affinity map: Information from the sensor robot and mobile app to find out the users' needs, and the user journey map (right side, for persona) facing the sensor robot, in the highways/roads.

Both near and distant solutions for given road information are required, based on the findings from the user journey map, as shown in Table 2. An adjacent sensor robot device in the car accident area can provide solutions to nearby drivers by directly projecting a message from the robot device. To project the message in optical rays, at least one manipulator is required to achieve the desired angle (of laser projection). The simplest manipulator in a laser projection unit is an actuator, a base, and an R-R manipulator that rotates a total of two turns each time just before the end-effector. It is useful for projecting forward light rays to emphasize the bypass path.

The requirements of distant users from the road in issue can be solved by communication from sensor robots to the access point server. Stable IoT communication via wireless TCP/IP using the LoRa module available with a mobile phone telecommunication network.

The design for the manufacturer requires assembled and linked products for distribution. Further product validation is required for the distribution of the product in the scalable production process. According to the total design process in Figure 8.3, implementation of an industrial model of sensor robot hardware as Ill as an alpha-released mobile app in Figure 8.6 was to deliver information for targeted users.

In this section, the architecture of the sensor robot system used in this research is introduced first. Next, the connected network of APIs and three case studies of mobile apps according to the extracted needs from the design thinking are presented and discussed. As the result of design delivery, the overall information architecture of the process (from the robots-networks to APIs-mobile app) is shown in Figure 6. It is then summarized to support the different, wise, and refreshing way to commute to work. Lastly, the discussion of the results is provided with examples.

The background information mentioned in Section 8.3 was used for the derivation of robot design, reflecting the needs of the users. The sensor robot device is an automated input device stationed on the highways/roads, and has communication dependency with other robots as an access point. According to the requirements from the

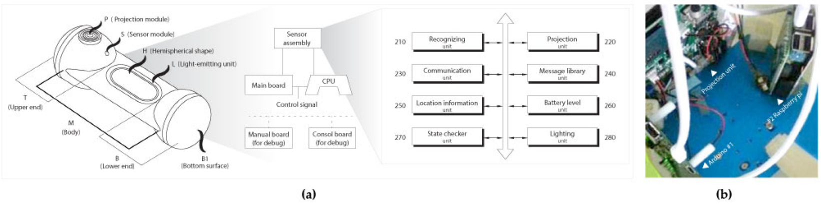


Figure 5.48: Vehicle induction: information generation from the robot device via access point function

needs-based function list, the architecture of the sensor robot has a sensor assembly comprising recognizing, projection, communication, message library, location information, battery level, state checker, and light units, as shown in Figure 8.8.

Figure 8.8 shows the schematic labeling of each portion of the robot device. The robot includes an upper end (T), body (M), and loIr end (B). T is positioned above M and includes a projection module (P) and sensor module (S) for projecting an image and detecting approaching vehicle, respectively. The projection module can be in at least one configuration of the image projection unit and the detection sensor module of the robot device.

The recognition unit (the detector, labeled as 210 in Figure 8.8) uses an ultrasonic sensor to measure the distance to the vehicle approaching the sensor robot device. The detector uses an ultrasonic to a RADAR (or LIDAR) sensor, which uses frequency bands in the range of 20 kHz to 79 GHz to measure the distance from an object. Besides the ultrasonic sensor, the detector includes a sensor equipped with a position-sensitive detector sensor, a charge-coupled device image sensor, and an infrared (IR) sensor to identify the presence and distance of the vehicle. The recognition unit periodically measures the distance betIen the robot device and the vehicle. When the measured distance betIen vehicles is close to 0–200 m, the vehicle is considered to be approaching the robot device. The recognition unit then generates access information when an approaching vehicle is detected. Here, the “access information” refers to information about the detection of the approach of a vehicle to the robot device and includes at least one piece of unique identification information of the robot.

The sensor robot device also includes an image projector (220 in Figure 8.8a) in the projection unit (220 in Figure 8.8b). It projects an image or text with a laser and lighting onto a road surface when the vehicle approaches. Here, the projected image can include a video or image message that notifies the driver of a road condition or a detour route. Also, the image as safety lighting can include a warning message indicating the state of the road. For example, a warning video can consist of a message indicating the state of the road, such as “under construction” and “incident section.” The projected image can also indicate a detour route. For example, the ‘detour route image’ can include a message indicating a direction in which the vehicle should bypass, such as ‘-¿’ and ‘¿¿¿’. In this case, the image to be projected can be set by the image manager of the message library unit (240 in Figure 8.8a). The image projector can project an image onto a road surface when the approaching vehicle is within a preset range set by the detector. For example, when the ultrasonic detector detects a distance that is feIr 10 m and RADAR detects a distance of less than 200 m from the approaching vehicle, the image is projected on the road surface to warn the driver. For efficient battery usage, it can stop projecting an image while no vehicle is approaching the robot device. The image projector includes a light source unit inside the package. I adopted a light source unit including red, green, and blue laser diodes and connected it to Arduino, as shown in Figure 8.8b. In this case, the plurality of light-emitting devices can emit color by combining at least one white beam. The light source unit can emit light generated in each of the laser diodes by a driving current applied from the poIr supply unit (260 in Figure 8.8a) according to a predetermined driving signal. It can also control the projection angle to project the image within the distance measured by the detection unit. Here, for the purpose of setting the accurate angle of the laser lighting, the projection manipulator, as shown in Figure 8a, controls the image projector to project an image on a road surface within a distance from the vehicle, measured by the detector, based on a vertical axis relative to the road surface. A portion of the robot device can also be horizontally rotated to control the projection angle.

The communicator (230 in Figure 8.8a) can transmit and receive wireless data to and from the operator terminal or other robot devices using a mobile communication module on a short-range communication band. The near field communication module is for near field communication and is internally equipped with Bluetooth, Radio, WIFI Direct (WFD: TCP/IP), NFC, and a universal serial bus (USB). The robot device can configure an ad-hoc network with the operator terminal or at least one other robot device through the communication unit, which transmits the access information generated by the recognizing unit to the operator terminal or other robot devices.

The image manager can include a module for managing an external storage device, such as a USB memory stick, to manage at least one image stored in the external storage device. The message library (240 in Figure 8.8a) can set an image to be projected by the image projector. For example, the image to be projected by the image projector can be set based on the image setting information received from the operator terminal through the communication unit. Here, the image setting information includes identification information of an image to be projected according to the unique ID of each robot device, which can be a combination of numbers or letters for distinguishing each image. This includes the symbol of a bypass path or warning. When the identification information of an image, including an 'under construction' message among warning symbols, is received from the operator terminal through the communication unit, the image projector can be configured to project a warning image matching the identification information of the received image.

The image manager includes an input unit (interface) capable of receiving image setting information. When the operator inputs image setting information through the input unit, the image manager can include one or more images. The image manager can also set an image to be projected among at least one image based on the image setting information stored in the external storage device. The operation is based on the location information of the robot device obtained by the location information unit (250 in Figure 8.8a). For example, when it is determined that the robot device is within a preset range at the traffic accident point, based on the acquired location information, the image manager views the warning image to be projected by the image projector in an ‘accident occurrence’. The image manager can also determine which robot device is located closer to the approaching vehicle based on the acquired location information. Additionally, the location information unit can acquire longitudinal and latitudinal information of the robot device using a GPS and an indoor-outdoor positioning system. The location information of the robot device can also be obtained through a media access control address of a connected WIFI access point.

The robot device includes a battery level (indicator) unit (260 in Figure 8.8a). The battery level unit can receive poIr from an external or internal poIr source and supplies the energy required for each component of the robot device. The poIr supply unit includes a general rechargeable built-in battery that is replaceable. The loIr portion has a Iight greater than the Iight of the upper portion so that it can move like a portable machine when the robot device is installed, even if the robot device falls. Additionally, B includes the poIr supply unit of the robot device.

First, the robot device includes a state checker unit (270 in Figure 8.8a), which can check the operating state of each component of the robot device to generate state information. Accordingly, the ’status information’ refers to information on the operation state of each component of the robot device: the detection unit, the image projection unit, the communication unit, the image management unit, and the location information unit. Information about the operation state of at least one of the information and poIr supply units is included. Information on the remaining battery charge of the poIr supply unit is also included. Furthermore, the status checker can cause the light emitter (280 in Figure 8.8a) to illuminate to notify an operator when the remaining charge in the battery is within a preset, remaining range. Second, the state checker unit can check the communication state of at least one other robot device through the communication unit. The status checker can store unique identification information of each robot de-

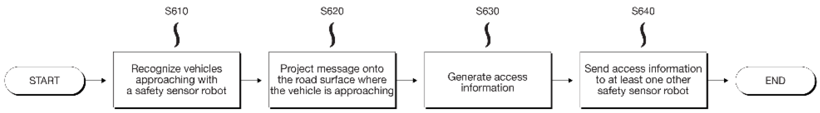


Figure 5.49: Process diagram: Sensor robot communicate via network infrastructure - API - mobile app.

vice connected through a network, periodically check the communication state with at least one other robot device and communicate with other status checkers. Unique identification information of a robot device can also be extracted. In this case, the status checker can transmit the extracted unique identification information of the robot device that cannot be communicated to one of the operator terminals or another robot device through the communication unit, in which case, the light-emitting unit can also emit light. Third, the status checker includes a gyro sensor and can, therefore, determine whether the robot device has moved or fallen based on the motion information detected by the gyro sensor. If it is determined that a robot device has fallen, the state check unit generates state information indicating that the robot device is inoperable and is communicated by the communication unit to at least one other robot device or the operator terminal.

The robot device includes a light-emitting unit (280 in Figure 8.8a). The light-emitting diode (LED) light [26] emits light based on the status information generated by the status checker and is set by the operator terminal. For example, white light is emitted when the robot device is operational, and the remaining battery charge level of the poIr supply unit in the status checker is within a preset range. A green light indicates that the communication of at least one other robot device is impossible.

The vehicle guidance method includes steps that are processed in time series in the robot device shown in Figure 8.9, Figure 8.10 and Figure 8.11. The flowchart in Figure 11 is an exemplary view for explaining the method of inducing a vehicle by the robot device.

The robot can detect the vehicle (300 in Figure 10a) approaching the robot device

Table 5.11: Findings from the voice-of-user, near a car accident area vs. distant from the road in issue.

Car accident area(near)	Prompt report	Anxious users	Collect for accident facts	When moving to a safe place
Distant from the road	Prior information registration required	Need service proposal	Accurate status record	Choice based on user simulation

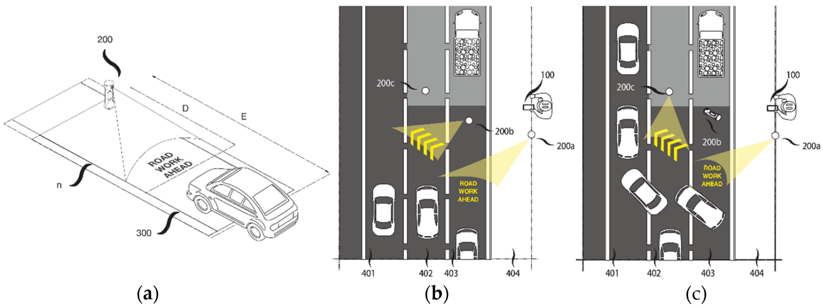


Figure 5.50: An example view explaining the vehicle guidance system: (a) vehicle guidance method betIen the robot device (200) and vehicle (300). D is the distance betIen the robot device and vehicle and E is the preset range; (b) in normal communication among 200a, 200b and 200c; (c) communication betIen 200a and 200c is available even when the robot 200b is damaged.

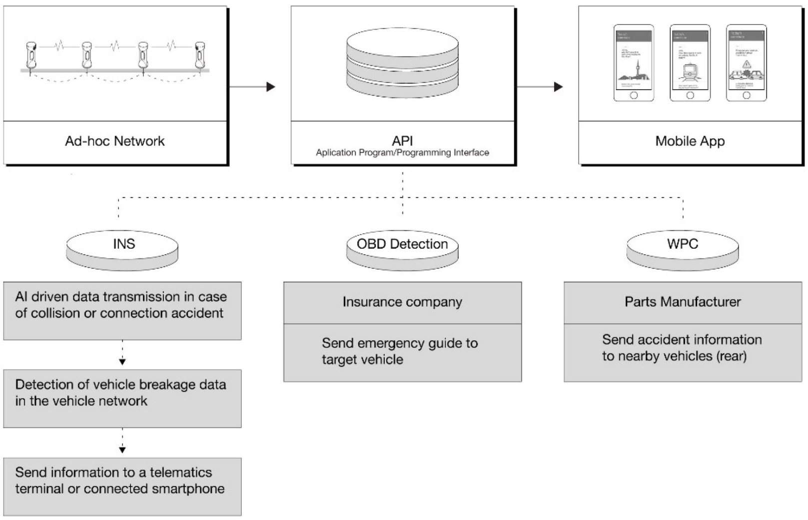


Figure 5.51: Data flow: vehicle guidance system, from sensor robots to in-vehicle service network.

(S610 in Figure 11), then measure the distance D from the vehicle. For convenience, the distance D betIen the robot device and the vehicle is expressed perpendicularly to the vehicle while being parallel to the road surface. The robot periodically measures D from approaching vehicles. If a vehicle is detected as approaching, the robot projects an image on to the road surface R of the approaching vehicle (indicated by S620 in Figure 11). Figure 11 includes a warning image with an under construction ('road work ahead') sign. The safety robot device can: Project an image on the road surface R on which the vehicle is approaching, when the distance D with the vehicle is within a preset range E. For example, E can be set to 200 m, and the robot detects an approaching vehicle when D is detected to be within 200 m. The image is then projected on the road surface R. Control the projection angle to project an image on R within D from a vehicle and project the image according to the projection angle. Generate access information when the vehicle approaches the robot device. Transmit the access information generated by at least one other robot device The first robot (200a) in Figure 10 can detect the approach of the vehicle and project a warning image on the road surface. It also generates access information and transfers the generated access information to at least one other robot device, say 200b. The second robot receives the access information from the first robot and projects the detour path image. Furthermore, when an error occurs in at least one of the robot devices, the third robot device (200c) can replace the robot device in which the error has occurred, as in Figure 10b,c. The third robot device can determine whether an error has occurred based on the state information received from the first or second robot device. Alternatively, the third robot device can extract the unique identification information of the non-communicable robot device to identify the failing robot device. When the second robot device is damaged or felled by a vehicle, the second robot device provides its status information to the first and third robot devices and at least one operator terminal through peer-to-peer communication. The status information includes the unique identification information of the second robot device. Image setting information, which contains the information about the image set that needs to be projected by the fallen second robot, is also transmitted to the first and third robot devices, and the operator terminal. In this case, the operator terminal displays the received status information and the operator checks the status information so that the third robot device can operate to replace the second robot device. For example, when the third robot device receives status information indicating that the third robot device has fallen or moved from the second robot device, the second robot device matches the identification information of the robot device in which the error has occurred. The error-prone robot device is identified and the second robot device, which is an error-prone robot device, can be projected based on the image setting information received. When the second robot device is in an emergency state where communication is impossible, the third robot device extracts the unique identification information of the second robot device. The image set in the second robot device can be projected from the image setting information based on the unique identification information of the second robot device. At this time, the image setting information includes identification information of the image to be projected according to the unique identification information of each of the devices. The third robot device projects an image of which at least one image stored in the image manager matches the identification information of the image. Along with the sensor robot device, the vehicle guidance system is applied to road construction and traffic accidents. Even if it is necessary to guide the vehicle through the bypass route, the technical idea is applicable. The vehicle guidance data flow is described in Figure 8.11. The guidance system includes instructions executable by a program module instance from the sensor robot, through the API server, to the Android mobile app. The in-vehicle system can process instructions within the computing device, such as displaying graphical information for providing a graphical user interface on an external input or output device (such as a display connected to a high-speed interface through On Board Diagnostics (OBD) [27] with an Android mobile app).

In data collection for an alternative pathway to guide users, the first requirement

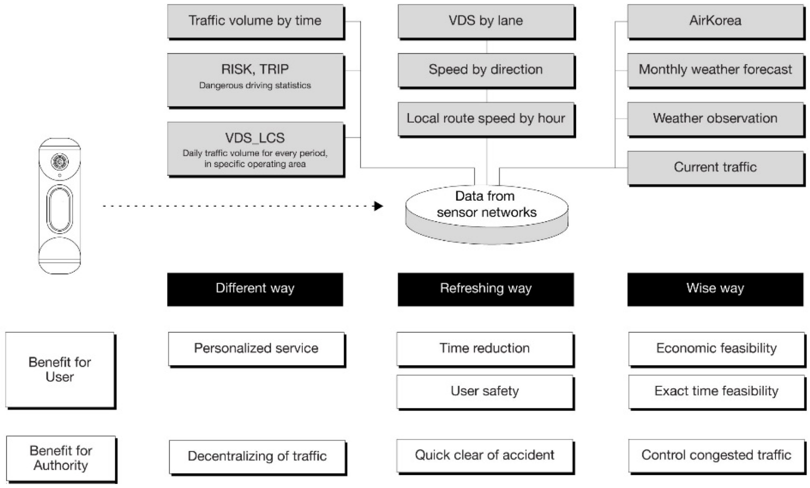


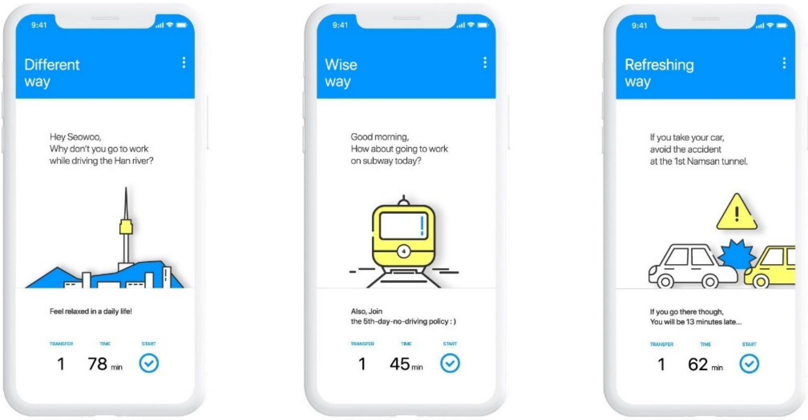
Figure 5.52: DB of "Different way to work", "Wise way to work", "Refreshing way to work" linked to APIs

is the personalized driving experience. The display for the different way to work is shown in Figure 12. While using the different way to work function, users can be guided toward the best route using big data (car accidents, traffic situation, rest area, drowsiness rest area) from collected data, such as the highway information API, as shown in Figure 8.12

The application will suggest to commuters a different route to that which they used to use. The app finds the optimal route using big data APIs (weather, current traffic conditions, rest stops, shelters) according to user sleep time and custom arrival time settings, and daily weather and fine dust information.

Driver (user)-generated features are mainly focused on understanding the individual patterns and operating as a service tailored to the individual. The application will also link products like (1)personalized service for rush hour pass to work, (2)decentralized traffic which is congested, (3)traffic measurement and notification by time.

When building the DB, a personalized information service for the user is the first aim. Authorities can also help to control the congested traffic from decentralized resources with various APIs.



(a) (b) (c)

Figure 5.53: Display of (a) “Different way to work”; (b) “Wise way to work”; (c) “Refreshing way to work” in the mobile application.

In wise way to work, data requirement is personalized arrival time. The display for a wise way to work emphasizes a new experience component by attracting commuters to select the alternative route (e.g., avoiding sleepy drive, misty highway), as shown in Figure 13. While using the “Wise way to work” function, users are offered the best route using big data (weather, traffic jam, delay zone, black ice, and so forth) from collected data, such as the weather information API.

When designing the database, a personalized information service for the user is focused upon. The authorities can also control congested traffic from decentralized resources from various APIs.

For example, I resourced from the APIs of ”Current traffic”, ”Monthly weather forecast”, ”Weather observations of a specific area around the road”, from Korean government open APIs (at molit.go.kr) and ”Dust” - PM10, PM2.5 from “Air Korea”

Along with the weather, road conditions are an important factor for users to decide which route to drive. Depending on precipitation, fine dust, road conditions, etc., car pools, public transportation, and personal mobility recommendations can be provided via the app. The function suggests the better commute (e.g., only today, from home, to work) information. For instance, spread by public transportation, the load on the road can be decreased while temporary “black ice” appears in the pathway.

The data for the alternative pathway to guide the user for case 3 requirements are personalized to offer an enjoyable journey. The display for the refreshing way to work emphasizes the new experience component to attract commuters to select an alternative way, as shown in Figure 8.13c. While using the “Refreshing way to work” function, the user can get the best route using big data (event, travelers’ site, density on the bridge) from linked information in the APIs like ”VDS by lane, speed by direction” and ”Local route speed by hour”.

In developing the database, along with both safety and time reduction, which are important for users in the “Refreshing way to work” mode, authorities can assure quick clearing of accidents on the road resourced from clouded sensor robots and various open APIs.

In summary, the research results show that the sensor robots and mobile app mainly operated from 6 a.m. to 10 a.m. and provided customized service by modifying/solving uncommon sudden events on the road quickly. I aim to integrate safety and efficiency with convenient apps through a terminal designed with a proven system based on big data. The system focuses on the safety of the user and prioritizes safety and convenience of use. Information architecture of user experience is shown in Figure 8.14.

I introduced safety lighting systems and interfaces to interoperate robots and gather information. Based on the cooperation of relevant agencies, I simulated in the same external environment as the actual highway and implemented a verification method by implementing and testing the lighting that indicates a safe bypass. The information architecture was designed to provide three contextual value services to users. The AI-based value creation proposed by this system leverages data from road traffic environments and map information systems to help coordinate overall traffic. The three case studies, [6]—(1) Different way to work, (2) Wise way to work, (3) Refreshing way to work—seek to instill a happy memory of the commuting journey. To all users

Table 5.12: Data type and causal inference in DB of “Different way to work”.

Index(type)	Traffic Volume	RISK	TRIP	VDS_LCS
Data Type	Traffic volume	Place Data	O-D Data	Travel time
Causal Inference	Instrument	Instrument	Instrument	Confounder

Table 5.13: Data type and causal inference in DB of “Wise way to work”.

Index(type)	Current traffic	Monthly W.forecast	W.OBS.area	(Dust) PM10	(Dust
Data Type	Traffic volume	Weather data	Place data	Weather data	Weath
Causal Inference	Instrument	Confounder	Confounder	Confounder	Conf

Table 5.14: Data type and causal inference in DB of “Refreshing way to work”.

Index(type)	VDS by lane	Speed by direction	Local route speed by hour
Data Type	Travel time	Speed data	Speed data
Causal Inference	Confounder	Instrument	Risk factor

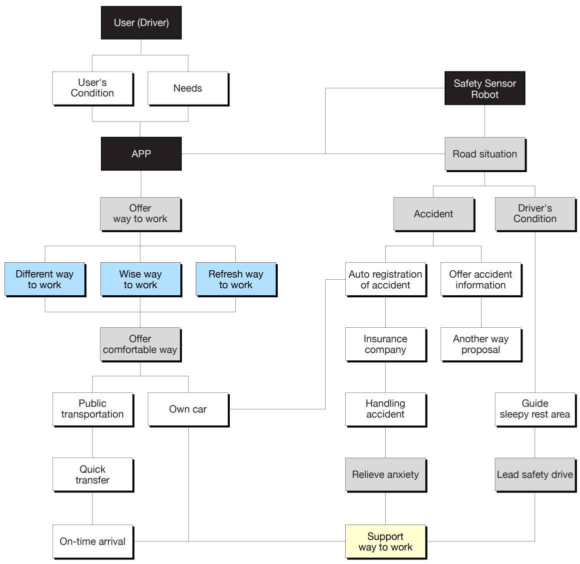


Figure 5.54: Information architecture that aims for a comfortable commute experience

who commute through highways/roads, this application will contribute to creating a balanced condition by providing stable route options, as shown in Figure 8.15.

To estimate a causal effect on a target population Q (the number of commuters), the task of predicting the distribution of outcomes Y after intervening on a variable X, written Q = P(Y = y—do(X = x)) [23]. This information is available to us from an observational study (Traffic Volume). This is the standard task of policy evaluation, where controlling for confounding bias shown in Figure 8.16 which is resourced from (Bareinboim and Pearl, 2015).

Investigating from the benchmark of "RITIS" [20], I found strategies to inform individual users as well as a public transportation data center on road conditions. Same as the use-case, as shown in Figure 8.17, demonstrates, multiple safety sensor robots working in the middle of highway and roads can engage in robot-to-robot communication in an ad-hoc network.

As the result of research, the optimized strategy to design is to design a whole system, but not at once. A matrix structure with smaller units can gather with modules in their functional category via data-driven calculation support for designer. Modular approach is risk-flexible as well as changeable evolutionally.

5.9.2 Summary of Case Studies

This subsection gathered summary of case studies and information channel modeling from the factory, through delivery, to consumer sales. According to those three case researches, I found the answers for the research question.

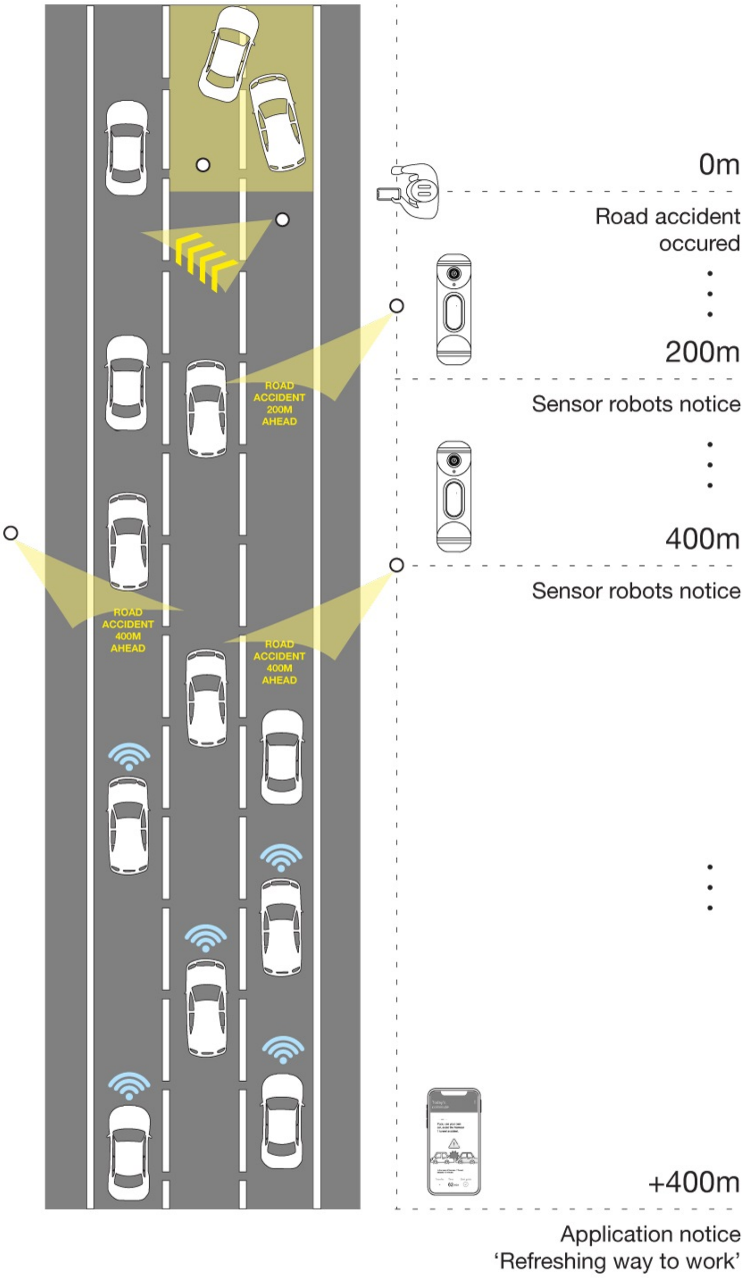


Figure 5.55: Simulation of a comfortable commute experience

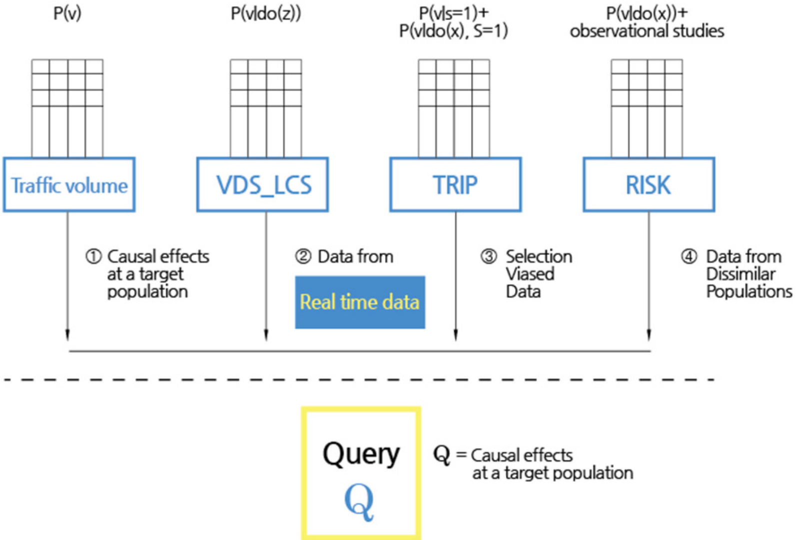


Figure 5.56: Estimation of causal effect at target users commuting in the morning.

Figure 5.57: Convergence scenario from safety sensor robot to inform mobile application including 3 user experience concepts and 3 functions converged into 3 mobile app services.

Figure 5.58: ***

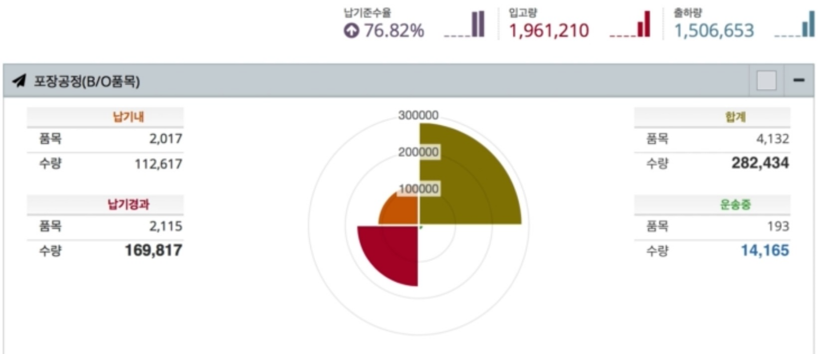


Figure 5.59: ***

5.9.3 Background and Input

5.9.4 Data Process from Factory to Designer

5.9.5 Output to Designer

5.10 Delivery Level

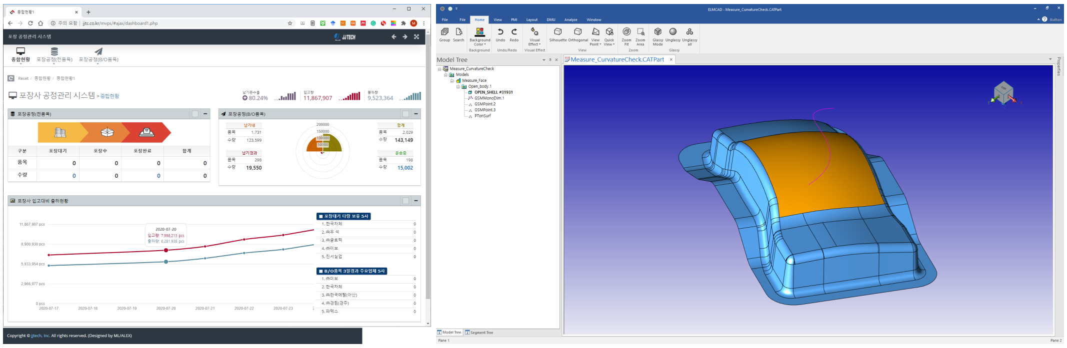
5.10.1 Background and Input

5.10.2 Data Process from Inventory to Designer

5.10.3 Output to Designer

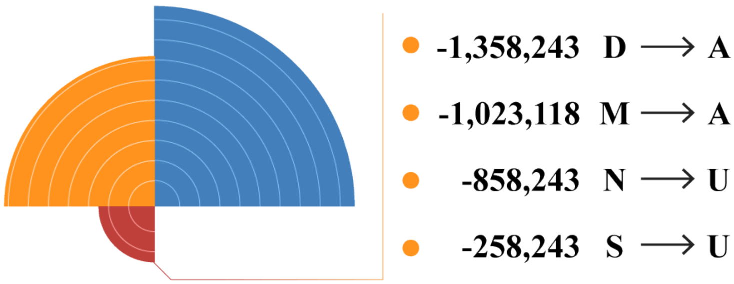
Chapter 6

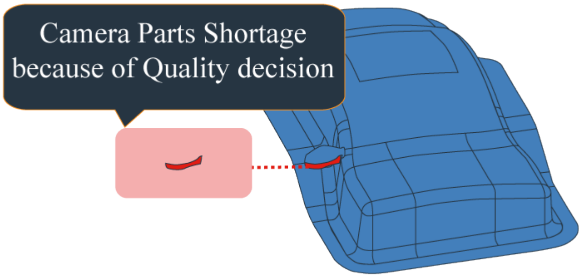
Two Applications for Vehicle Designer

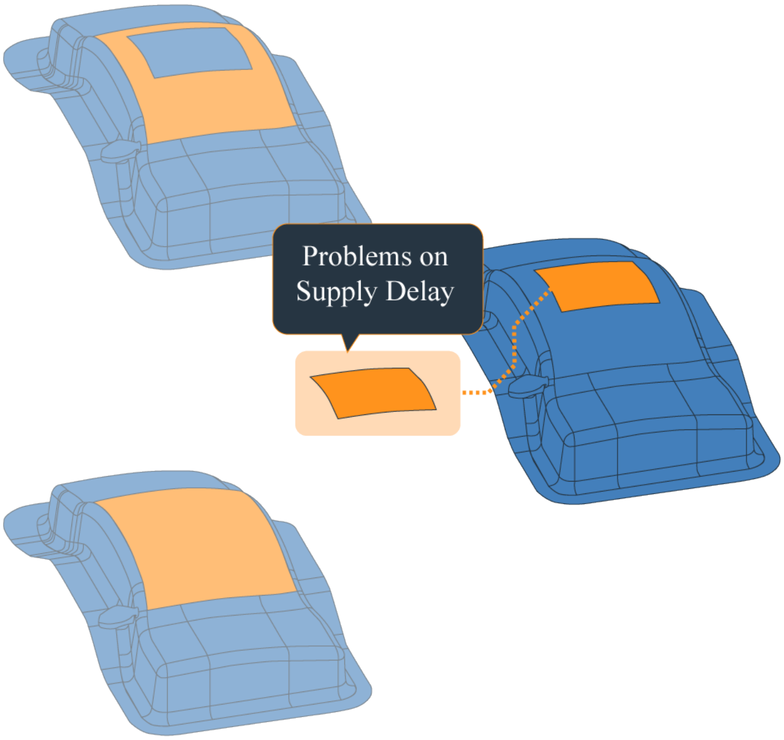


6.1 Real-time Dashboard DB for Decision Making

For the purpose of providing design clues simultaneously, information integration for designer is implemented with another filtered system for parts journey from manufacturing, through delivery, to consumer sales.




Camera Parts Shortage
because of Quality decision



6.1.1 Searchable Infographic as a Designer's Tool

6.1.2 Scope and Method

6.1.3 Implementation

6.1.4 Result

6.1.5 Evaluation

I launched the part searchable dashboard in the website http://jjtc.co.kr/mvps/ since October 2017.

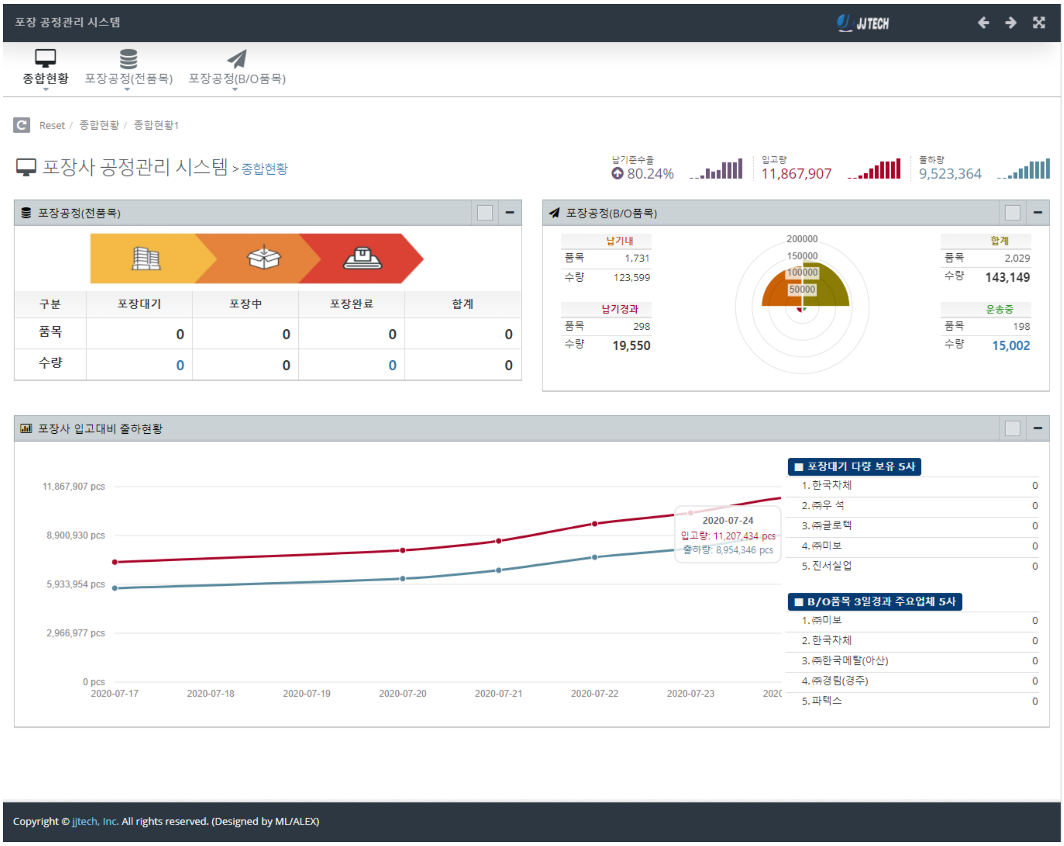


Figure 6.1: A screenshot of the Searchable Inforgraphic Dashboard.

6.1.6 Summary

Information requested by users is becoming more and more customized. In the automotive designer's work environment, various interactions such as business, manufacturing, delivery, and consumer decision-making will be reflected in the designer's decision making. In the near future, as various types of web publishing suitable for providing personalized information are customized, it is expected that the role of designer's UX improvement that can help designers to communicate various data is necessary.

6.2 Application to CAD for vehicle designer

6.2.1 CAD as a Designer's Tool

Currently, the limitations of 3D CAD management tool, as well as the incompatibility of 2D drawings and 3D models, is an obstacle in efficient data distribution. The proposed program intends to unify 3D models and 2D blueprints in order to minimize missed information risk as well as human error caused by the discrepancy between the two forms. This also maximizes data availability during the follow-up production process, and allows 3D models to be used more freely throughout the entire production process.

6.2.2 Scope and Method

The objective of the CAD is designed to be affordable, intuitive and lightweight, yet contains a wide range of robust functionalities.

6.2.3 Implementation and the Display of the CAD Software

As its strengthened point, the CAD applies web-based 3D PMI(Product Manufacturing Information) display solution to its program. It also applies drawing descriptions with on-site information to its model component visualization, which makes data-driven design such as Smart Factory possible.

The CAD software platform is suitable for application on various AI packages, such as eye-tracking technology, based on prior collaboration on AI research such as the development of web program with its eye-tracking usability test.

As a program based on the Microsoft Windows software framework, the UI of the CAD program closely mirrors that of Microsoft Visual Studio based products. The toolbar on top of the screen has four parent categories: [File], [Home], [View], [PMI and DMU]; which are each subdivided into more specific subcategories, which each contain the individual tools that allow the user to view, edit, and add PMI to the 3D model.

The right-hand viewing window can display both the 3D model and PMI in the same space, so that the user can intuitively understand the product.

6.2.4 Result

Productivity and Cost Effectiveness: Instead of CATIA, the program predominantly used within the companies in motors group, the CAD itself designed its program to utilize a smaller scale, cost-effective domestic resource firstly from Techsoft.

In its eco-friendly aspects, the program is designed to optimize the parts, and reduce the number of redundant material parts in the design. By doing so, it helps designers reduce the use of unnecessary parts, create as little material waste as possible, and prevent overconsumption of natural resources.

6.2.5 Evaluation: Usability Test with Eyetracking

To evaluate the CAD software as an information supply tool, the program is designed so that users with all levels of experience can use the product in its universal design aspects. Because the CAD program UI reflects that of Microsoft Visual Studio based products, many users will already be familiar with the basic UI format, because of the wide availability of the Microsoft Windows software framework.

I scheduled two usability tests: pilot-alpha for stakeholders and open-beta for novice CAD users. About the Windows version of CAD system, displays and tasks were evaluated to evaluate the hypothesis and confirm the function like below:

The four main toolbar menu options, [[File], [Home], [View], [PMI and DMU], are intuitive categories of the vast array of tools in the program without overwhelming the user with too many options from the start. I confirmed the ergonomic facts of the CAD system like below:

- Ease of Use: The program initially had CATIA users as the default target when designing the user interface. However, when users first log into the site, they can choose the 3d interface they are most familiar with, which the UI will reflect by changing to match their program of choice. This makes the program intuitive to use for users of any kind of prior experience.

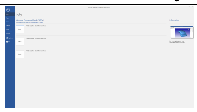
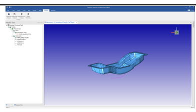
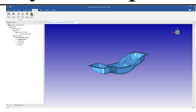
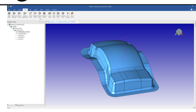
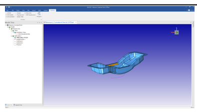
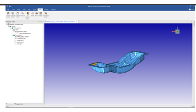
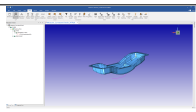
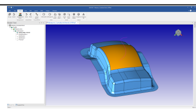
- Emotional quality: With data on emotional and quality satisfaction levels from the users regarding vehicles that were sold early after initial release, the designers receive feedback on the vehicle settings that were most preferred by users, so that they can be kept in future iterations and designs.

- Efficiency: Performance speed was higher than past software and response time was reduced to allow users to review CAD files in a shorter amount of time.

The program utilizes fool-proof design for ecosystem safety when applying parts to a product during the design stage. If the part is a prohibited item or material, the part will be displayed in red, and will not change colour, indicating to the user that the part or material is unsafe for use. The aspect for usability and safety is specified below:

- Usability: User tests involving eye-tracking were used to improve the design so that users could easily learn and use the program.

Table 6.1: Task for usability test in Windows CAD system representing information

#before				
#tasks	Open and load	Design modify	PMI check	Parts info
#after				
User A-1	V	V		
User A-2		V	V	
User A-3		V		V
User A-4			V	V
User B-1	V	V		
User B-2		V	V	
User B-3		V		V
User B-4			V	V

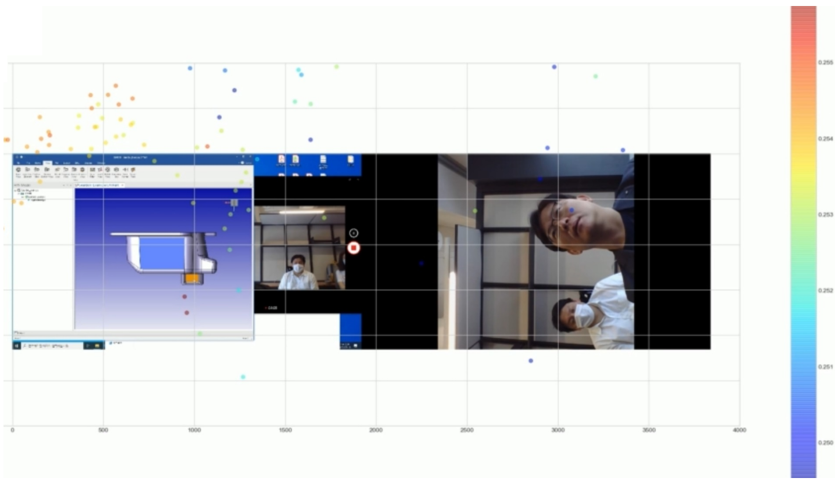


Figure 6.2: Eyetracking analysis for pilot-alpha test

- Safety: The program utilizes fool-proof design when applying parts to a product during the design stage. If the part is a prohibited item or material, the part will be displayed in red, and will not change colour, indicating to the user that the part or material is unsafe for use. Also, if the parts are assembled incorrectly, they will also be displayed in red before moving on to the next stage, to indicate that it needs revision.

6.2.6 Summary

It is possible to reduce the risk of future trial and error in the design process by using the verification unit module made in the form of linked parts cluster accelerated by the electronic change of the vehicle. Implementing a new information provision method provided as color and dialog add-on to the CAD tool through a summary of summary of modeling methods of designers, securing a channel for providing information through case studies on processes from manufacturing to consumer sales.

I verified the universal point and ergonomics in the application through usability test including eyetracking. Within the application of searchable inforgraphic dashboard and CAD system, it is necessary to create an interlocked design by dividing the entire system into small parts units connected to each other, rather than designing them all at once. Through this segmentation approach, it is possible to flexibly respond to risks and to design custom modules that can undergo changes for vehicle designer.

Chapter 7

Conclusion

7.1 Summary of Case Studies and Application Release

The current conflicts between automotive manufacturers and third parties often result in superfluous resources being consumed or impeding the design processes. The proposed system, finally applied to the CAD software for designers, that utilises three information channels solves such problems, helping vehicle designers monitor module components independently and enhancing efficiency in the automotive industry.

The first of the three information channels is the real time data visualisation of module production in factories. This type of information processing occurs in the plant manufacture level, and allows designers to check the status of production and the quality of the artefacts created. Without a mediator to transfer the information from factories to designers, time and labour, in addition to financial resources, can be preserved. Additionally, if a designer can directly monitor and request for component productions, customization of automobiles according to client's preferences or the requirements of a specific case, such as a car accident, will be achieved more readily.

The second information channel is the exchange of data between an internal camera within an automotive specification and the inventory and distribution center. The connected flow of data between the car and the supplier of module components would begin at the procurement of the automotive parts, and help take appropriate and immediate action to any unfavourable changes in the condition of the vehicle.

Lastly, the real time database on the components of a vehicle is, as the other two are, a powerful channel of information that can bring benefits to both automotive designers and customers. The use of a public API and sensor-stimulated IoT does not only enable an immediate access to data, but also expands the network of data. Through this system, the damage on a car can be determined and repaired instantly on the site of accident, and designers can gain an insight into how parts replacement takes place and apply this knowledge to improve automotive designs to help them prepare for any unexpected accidents.

According to those three information resources, an application ”Packaging System” represents input and output parts manufacturing and delivery quantities in infographic with search-able interface. The information delivered through the three aforementioned channels is categorised by module components and the designers are able to view it colour-coded on the CAD software.

Those systems offers comprehensive data that encourage flexibility in the automotive design process, while ensuring the correct and necessary information to be applied to the design. It is expected with enthusiasm for the proposed system to reinforce the standards of contemporary vehicles.

7.2 Impact of the Research

From display interface to body package, I took part in the several trials in the vehicle company as a vehicle designer. As a designer and a developer working in-house of automotive industry, I experienced a lot of conflicts among various teams. Design is strongly important, but not applicable when it is out of federal laws. Standards, quality guidelines, production engineering opinions are sometimes in the collision with the design direction.

As results of the research, both dashboard application and CAD system as well as data systems from case studies are currently reflected to the design ecosystem of the motors group. From alpha and beta tests to the release, data-driven design is supported by concluded systems from the research.

7.3 Further Study

The research must go on with the further approaches with automotive industry economy. In the further study, I will focus more on vehicle model to find which aspects make popular model for used car.

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초 록

자동차 산업은 친환경 전기/수소 자동차의 확대와 제조 공정에서의 모듈 단순화를 통해서 외부 환경의 변화에 따른 새로운 국면을 맞이하고 있다. 하지만 기존의 자동차 산업에서 구조화된 생산 가이드라인과 기간 단위 생산 계획에 맞춰진 여러 이해관계자들과의 갈등은 변화에 대응하는 방안이 관성과 부딪히는 문제로 나타날 수 있다. 예를 들어, 갑작스럽게 생산에 필요한 부품을 변경해야 하거나 특정 상황에 적용되는 디자인을 변경할 경우, 주어진 가이드라인에 따라 디자이너가 직접 의견을 반영하기 어려운 경우가 많다.

자동차 디자인은 차종의 철학과 이념을 나타내고 해당 차량제원으로 최대의 가치를 끌어내고자 하는 종합적인 과정이다. 본 연구에서는 여러 원천의 데이터를 기반으로 자동차 디자인 과정에서 활용할 수 있도록 디자인에 필요한 부품/모듈 구성 요소들에 대한 정보를 실시간으로 표시해주는 시스템을 고안하였다. 이를 적용하여 자동차 디자인 과정에서 예상 못한 외부 문제가 발생했을 때 선택할 구성 부품을 대체하거나 사전에 해당 부품을 이해하고 디자인에 활용할 수 있도록 세 가지 정보 제공 채널을 구성하였다.

첫 번째는 자동차 공장 내 실시간 데이터 집계를 Google Analytics를 활용하여 시각화하고, 이를 공장 자체의 자가 성장 캐릭터에 반영하여 디자이너에게 제공하는 방식이다. 이를 통해 종합상황실 등의 복잡한 인력 체계 없이도 생산 및 품질 현황 데이터를 실시간으로 확인 가능하도록 하였다.

두 번째는 차량용 주차보조 센서 카메라를 차량 부착 뿐만 아니라 인벤토리와 물류센터의 CCTV에도 적용하여 주변상황을 인식하고 분석할 수 있도록 구성하였다.

차량의 조립 생산 단계에서 부품 단위의 이동, 운송, 출하를 거쳐 완성차의 주행 단계에 이르기까지 데이터 흐름을 파악하는 것이 디자인 부문에 필요한 정보를 제공할 수 있는 방법으로 활용되었다. 이를 통해 기존 이해관계자들의 큰 반발 없이 내부의 카메라 기능으로부터 부품 리소스와 운송 상태를 실시간 파악 및 기록 가능하도록 하였다.

마지막으로 공공 API와 센서 기반의 사물인터넷을 활용해서 도로 위 차량 사고가 발생한 위치에서의 현장 수리를 위한 차량 부품 즉시 수급 및 데이터베이스화 방법도 개발 되었다. 이는 디자이너로 하여금 가벼운 접촉 사고에서의 부품 교체 행태에 대한 소비자의 니즈(needs) 정보를 얻게 하여 차량의 디자인에 반영 가능하도록 하였다.

시나리오를 바탕으로 이 세 가지 정보 제공 채널을 활용할 경우, 자동차 디자인 과정에서 불러들여오는 부품 및 모듈의 구성 요소들을 디자이너가 정확히 알고 반영할 수 있다는 장점이 부각되었다. 정보 제공의 인터페이스를 쉽게 구성하기 위해서, 실제로 디자이너들이 자동차 개발 과정에서 디자인 프로세스 상에서 활용하는 CAD software에 세 가지 채널들로부터 들어오는 정보를 사례별 컬러로 표시하고, 이를 시선추적 사용성 평가를 통해 현업 디자이너들이 사용하기 쉽게 개선한 과정도 본 연구에 포함시켜 설명하였다.

주요어: data-driven, vehicle specification, context-aware, API, app, ioT

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